한국물리학회 원자분자물리 분과 워크숍

AMP 2026 초록집

Atomic and Molecular Physics Division Workshop (AMP2026)

워크샵 홈페이지: https://indico.kps.or.kr/e/AMP2026

8월 19일(수) 10:00 – 8월 21일(금) 17:00

무주리조트 카니발컬처 팰리스 (1F, 앙상블홀)

[Session A: Precision Metrology]

광시계의 현재와 미래

김휘동(KRISS)

Abstract: 국제단위계(SI)는 2018년 물리상수 기반 체계로 재정의되었으며, 시간 단위인 초는 여전히 1967년 정의대로 외부 섭동이 없는 세슘 원자 바닥상태 초미세 전이 주파수 (9,192,631,770Hz)를 기준으로 삼고 있다. 이를 구현하는 세슘 분수 시계는 상대 주파수 불확도 10^{-16} 수준으로, 수억 년에 1초 어긋나는 정확도를 가진다. 2000년대 초 광주파수 빗이 개발되면서 가시광 대역을 이용하는 광시계 연구가 본격화되었고, 구현 방식에 따라 광격자에 가둔 중성원자를 이용하는 광격자 시계와 포획 이온을 이용하는 이온 시계로 구분된다. 광시계는 빠르게 발전해 세슘 시계 대비 약 100배 향상된 정확도를 구현하였으며, 이에 따라 시간 단위 재정의논의도 지속되어 2026년 국제도량형총회(CGPM)에서 구체적인 로드맵이 검토되고 2030년 경광시계 기반 재정의가 유력하게 예상되고 있다. 국내에서는 한국표준과학연구원(KRISS)이 2000년대 초부터 이터븀 원자 기반 광격자 시계 개발에 착수하여, 현재 이터븀 광시계 1호기(KRISS-Yb1)를 운용하고 있다. KRISS-Yb1은 세슘 분수 시계 대비 약 10배 향상된 정확도를 구현하였으며, 2021년부터 2차 주파수 표준기로 국제도량형국(BIPM)에 등록되어 세계협정시(UTC) 생성에 기여하고 있고, 대한민국 표준시 UTC(KRIS) 생성에도 활용되고 있다. 현재는 KRISS-Yb1 대비 불확도를 추가로 개선한 차세대 이터븀 광격자 시계 개발이 진행 중이다. 이러한 초정밀 광시계는 주파수 표준기로서의 역할을 넘어 초정밀 양자센서 및 양자컴퓨팅 플랫폼으로도 활용 가능성이 주목받으며 다양한 분 야에서 연구가 확장되고 있다.

[Session A: Precision Metrology]

원자간섭계를 이용한 관성 센서 개발

이상범(KRISS)

Abstract: 원자간섭계는 냉각 원자의 양자 중첩 상태를 활용하여 가속도, 회전, 중력 등 다양한 물리량을 초정밀로 측정할 수 있는 핵심 기술이다. 본 워크숍에서는 고정밀 중력 측정에 기반한 기본 물리상수 측정, 물리 이론 검증, 지구물리 탐사 및 항법 등 원자간섭계 관성센서의 주요 응용을 간략히 소개하고 한국표준과학연구원에서 개발 중인 원자간섭계 기반 중력 센서의 최신 연구 성과와 기술적 진전을 공유한다, 나아가 현재 추진 중인 회전 및 가속도 센서 개발 현황과 향후 연구 방향을 간략히 소개하고자 한다

[Session A: Precision Metrology]

Optical Clock Comparison using Terrestrial and Non-terrestrial Networks

허명선(KRISS)

Abstract: As the scientific community progresses towards the redefinition of the SI second, ultra-precise optical clock comparisons have become essential to validate unprecedented timekeeping accuracies globally. This presentation reviews the current status of these efforts, highlighting diverse terrestrial and non-terrestrial network approaches such as optical fiber links, satellite communications, Very Long Baseline Interferometry (VLBI), the Atomic Clock Ensemble in Space (ACES), free-space optics, and transportable optical clocks.

[Session A: Precision Metrology]

Frequency Measurement of the Sr $^1S_0 \rightarrow ^1P_1$ Transition via Cross-Correlated Experimental Methods

이재훈(KRISS)

Abstract: We present a high-precision measurement of the Sr 461 nm resonance utilizing two distinct experimental methods. Because both techniques share specific experimental parameters, their systematic error budgets contain strongly correlated terms. This talk focuses on our methodology for cross-analyzing these two approaches. By modeling and bounding the correlated systematic shifts—such as wavelength meter uncertainties and light shift offsets—we demonstrate a robust evaluation of the total uncertainty, resulting in a finalized resonance measurement of 650.503 815(5) THz.

[Session B: Quantum Optics and Information]

원자 앙상블을 이용한 양자 과학

Quantum science with atomic ensemble

문한섭(부산대학교)

Abstract: 원자와 광자는 양자역학의 태동을 이끈 기본 요소이자, 양자과학 및 양자정보 기술의 핵심 축이다. 원자의 양자적 특성은 양자컴퓨터, 양자통신, 양자센서를 구현하는데 가장 선두에 있는 플랫폼이다. 또한 광자와 원자의 상호작용은 빠른 전송이 가능한 광자 큐비트 생성, 양자메모리 구현, 그리고 양자 리피트를 포함하는 장거리 양자 네트워크 구현을 위해서 중요한 역할을 한다. 양자적인 특성을 가진 양자광원이 원자와 상호작용을 하기 위해서는 원자가 가진 고유한 좁은 선폭의 공진하는 파장을 갖는 정확한 파장과 좁은 선폭의 광자가 필요하다. 본 발표에서는 원자 증기 셀에서 자발적 사광파 혼합과정 (Spontaneous Four-Wave Mixing)을 통해서 생성된 두개의 독립적으로 동작하는 편광얽힘 광자쌍 광원을 이용하여 고효율에 높은 성능을 가진 양자 광원을 개발하고 이를 이용하여 다양한 양자광학 연구를 수행함으로써 원자기반 양자광학 연구에 새로운 분야에 기여한 내용을 발표할 예정이다. 또한 원자 앙상블와 레이저와의 상호작용을 이용한 사광파 혼합 과정으로 구현한 압착광(Squeezed Light) 생성 및 연속 변수(Continuous Variable) 그래프 상태에 관한 최근 실험 결과도 함께 발표할 예정이다.

[Session B: Quantum Optics and Information]

Quantum Information in a Few Bins: From Nonclassicality Certification to Quantum-Enhanced Metrology

박지용(한밭대학교)

Abstract: How much quantum information can be retained in just a few measurement bins? In this talk, I will present theoretical and experimental studies showing that coarse-grained homodyne measurements can preserve the information needed for both nonclassicality certification and quantum metrology. A three-bin quadrature measurement certifies nonclassicality in Gaussian and non-Gaussian states beyond the variance criterion and can yield stronger finite-sample evidence than high-order-moment tests [1]. In phase estimation, an optimized estimator enables even a two-bin measurement to surpass the standard quantum limit while retaining Heisenberg scaling [2].

[1] C. Roh, Y.-D. Yoon, J. Park, and Y.-S. Ra, "Continuous-variable nonclassicality certification under coarse-grained measurement," Phys. Rev. Research 5, 043057 (2023).
[2] B.-Y. Go, G. Gwak, Y.-D. Yoon, S. Lee, N. Treps, J. Park, and Y.-S. Ra, "Quantum metrology under coarse-grained measurement," Opt. Express 34, 17346-17359 (2026).

[Session B: Quantum Optics and Information]

Quantum Optics via Stationary Light Pulse

김유신(POSTECH)

Abstract: Stationary light pulse (SLP), a zero-group-velocity optical pulse trapped in an atomic ensemble, provides a unique platform in which photons can be confined and manipulated in an atomic ensemble with long atom-photon interaction times while preserving their finite electromagnetic field nature. The capability to localize and control photonic excitations has established the SLP system as a promising interface between quantum optics and quantum many-body physics, opening new opportunities for engineering strong optical nonlinearities without an actual optical cavity. This talk reviews recent advances in SLP-based quantum optics and highlights the emergence of stationary photons as a versatile quantum platform.

The first part of the talk covers the coherent photon trapping in SLP systems. Experimental demonstrations of single-photon trapping and the simultaneous trapping of multiple optical pulses illustrate the preservation of quantum correlations and multi-mode capacity of the SLP system, providing essential building blocks for stationary photonic quantum systems. The second part addresses efficient interactions between stationary photons through two complementary theoretical proposals. Self-interacting SLPs are shown to realize the Lieb–Liniger interaction between stationary photons with optically tunable effective mass and interaction strength, offering a flexible platform for quantum simulation. In addition, Rydberg-interacting SLPs are introduced as a route toward long range interactions between stationary photons, enabling the deterministic generation and control of correlated two-photon states. Together, these developments demonstrate the potential of the SLP system as a novel platform for quantum nonlinear optics and quantum many-body physics.

[Session B: Quantum Optics and Information]

Quantum state tomography with generative diffusion model

이창협(한양대학교)

Abstract: Quantum state tomography (QST) is essential for characterizing quantum systems but becomes increasingly challenging in the presence of noise and limited measurement resources. In this talk, we present a generative diffusion model approach for QST that reconstructs quantum states from noisy and incomplete measurement data. Numerical results demonstrate improved reconstruction accuracy and robustness, highlighting the potential of diffusion models for scalable quantum state characterization.

[Session C: Light-Atom Interaction]

Quantum computing and simulation with trapped ions

김준기(성균관대학교)

Abstract: In the first half of this talk, I will present our work on the quantum simulation of topological systems using trapped ions. We experimentally studied the anisotropic quantum Rabi model (AQRM) and investigated its topological properties by preparing and characterizing both boundary and bulk states. Owing to the absence of translational symmetry, the bulk states exhibit a localization such as the boundary state. Nevertheless, topological observables, including chirality and spin–boson correlations, provide a clear distinction between the boundary and bulk states. We also reconstructed the phase-space distribution of the bosonic component of the boundary state and observed strong nonclassical squeezing.

In the second half of the talk, I will discuss our recent architectural study on scaling trapped-ion quantum computers through qubit shuttling. We propose a shuttling-based distributed quantum computing architecture in which entanglement is distributed by physically transporting qubits between processing modules. We evaluate its system-level performance and compare it with two representative architectures: the quantum charge-coupled device (QCCD) architecture and photonic distributed quantum computing.

[Session C: Light-Atom Interaction]

Nonlinear and non-Hermitian dynamics with trapped ions and cavity QED

이문주(POSTECH)

Abstract: We begin by discussing our experimental study of nonlinear mechanical oscillations in trapped ions. Specifically, we demonstrate the tunability of the Duffing nonlinearity of the ion oscillator, allowing it to transition from the softening to the hardening regime. Furthermore, when the ion velocity exceeds a critical threshold, we observe the formation of a phononic frequency comb in the ion's motional spectrum. By analyzing the experimental data, we reconstruct the phase-space dynamics and the Poincaré map of the ion motion.

The next part focuses on theoretical work with non-Hermitian dynamics arising when a single ion or atom is coupled to an optical resonator. When the strength of coherent interaction balances the dissipation rate, second- or third-order exceptional points can emerge in the system. In addition, we show that introducing a nanotip into the mode of a Fabry-Perot-type resonator enables controlled tuning of the dissipation rate. This capability allows us to generate an exceptional line and realize a dissipation-induced topological transition, in which the exceptional point can be tuned solely through the control of dissipation.

Finally, we present our experiments with a chain of approximately 100 ions. The ions can be individually manipulated and cooled close to their motional ground state. We discuss experiments on phonon hopping in the ion chain, as well as measurements of both the local and global density of states.

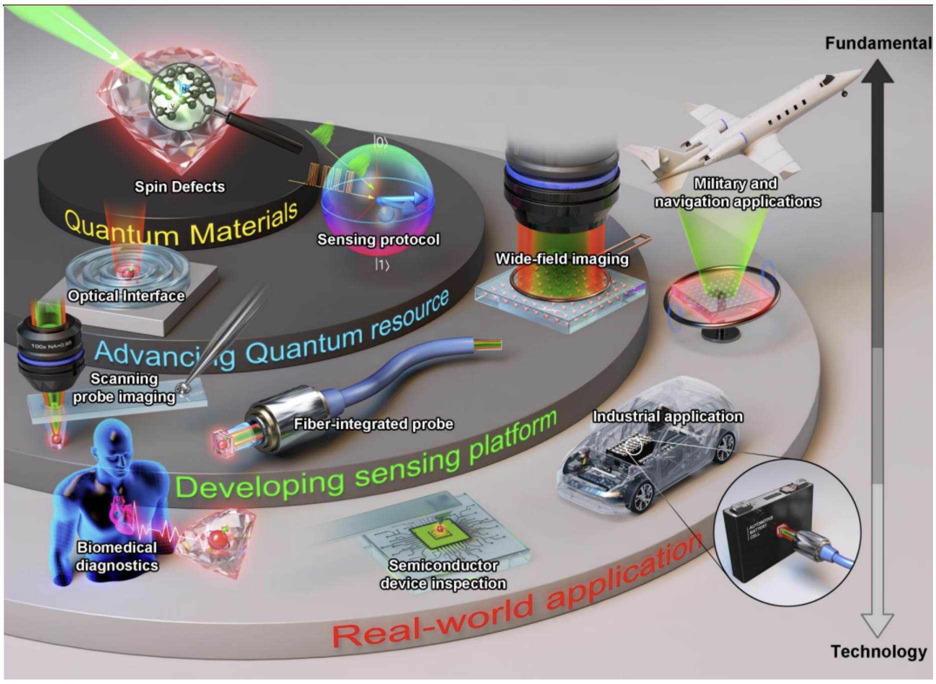
[Session C: Light-Atom Interaction]

Quantum Sensing with Spin Defects: Diamond Quantum Magnetometry

이동헌(고려대학교)

Abstract: Qubits are not only the fundamental building blocks of quantum information science and technology, but also powerful experimental tools spanning applications from fundamental research to industry. In this talk, I will present new opportunities enabled by spin qubits, with a particular focus on solid-state spin qubits based on nitrogen-vacancy (NV) centers in diamond. First, I will review our recent work on developing advanced quantum sensing methodologies, especially aimed at realizing nano-/micro-scale NMR and MRI. Then, I will introduce two quantum imaging approaches operating at different length scales: nanometers and micrometers. NV centers integrated with a scanning probe microscope are used to map stray magnetic fields from magnetic materials and current distributions in electronic devices at the nanometer scale. Ensembles of NV centers combined with a wide field-of-view optical microscope enable imaging of magnetic nanowires and magnetic structures at the micrometer scale.

Keywords: spin qubits, quantum sensing and imaging, diamond NV center



K. Kim *et al.*, Advanced Photonics 064002 (2025)

[Session C: Light-Atom Interaction]

Manipulating molecules using partial optical standing waves

조범석(UNIST)

Abstract: Optical standing waves are widely used to manipulate atoms and molecules, yet in practice they are rarely ideal. Unavoidable intensity imbalances between counter-propagating waves produce partial standing waves (PSWs) with nonzero intensities at nominal nodes, an effect typically treated as a minor imperfection. Herein, we show that PSWs readily form and fundamentally alter the molecular dynamics of nonspherical molecules by enhancing intensity-dependent alignment. Velocity-map imaging measurements of carbon disulfide (CS_2), supported by simulations incorporating rotational-state-dependent polarizabilities, reveal that the finite node intensity in PSWs can be exploited to improve the efficiency of quantum control of molecules. By reframing this experimental imperfection as a resource, PSWs offer a simple route to improved optical lattices and open new opportunities for molecular deceleration, dispersion, and state-selective manipulation, with applications in molecular and chemical physics.

[Session D: Instruments]

Laser based Carbon Isotope Separation Project in KAERI

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Abstract: 최근 원자력, 의료, 양자 등 다양한 분야에서 동위원소 소재에 대한 수요가 증가하고 있으며, 이에 따라 동위원소 분리 기술에 대한 필요성이 커지고 있다. 특히 탄소는 자연 상태에서 12, 13, 14, 세 개의 동위원소가 있는데, 탄소-12는 양자 및 반도체 분야, 탄소-13는 호흡 진단 등 바이오 및 의료 분야, 탄소-14는 표지화합물 생산 등에 활용되고 있으며 점차 사용량이 증가하는 추세이다. 이들 동위원소는 현재 탄소-12, 13은 저온 증류 방식으로, 탄소-14는 원자로를 통해 생산되어 공급되고 있으나, 생산량의 증가와 경제적인 생산 기술의 개발이 필요하다.

한국원자력연구원은 레이저 기반으로 다양한 동위원소를 분리, 생산하는 연구를 수행하고 있으며, 본 발표에서는 그 중에서 레이저 기반의 탄소 동위원소 분리 기술에 대해 소개한다.

우리는 레이저 기반의 분자법, 특히 폼알데하이드 분자의 동위원소 선택적 광분해를 이용하는 탄소 동위원소 분리 기술을 개발하고 있으며, 자연상태의 성분비가 1.1%인 탄소-13의 경우에는 단일 단계에서 99% 이상으로 농축한 세계 최고 수준의 결과를 보고하였고, 탄소-12에 대해서는 99.99% 이상의 농축을 실증하였다. 현재는 이 기술들을 탄소-14에 적용하는 방사성 폐기물 재활용 관련 연구를 진행하고 있다.

[Session D: Instruments]

Atom-based Quantum Sensors

문걸(전남대학교)

Abstract: Recent advances in quantum technology have accelerated the development of atom-based quantum sensors capable of measuring inertial and magnetic quantities with unprecedented precision. By exploiting the quantum properties of neutral atoms, these sensors provide absolute measurements with high sensitivity and long-term stability, making them promising candidates for next-generation positioning, navigation, and timing (PNT) systems. Representative examples include **cold-atom inertial sensors**, which employ light-pulse atom interferometry using laser-cooled atoms in vacuum, and **spin-exchange relaxation-free (SERF) atomic magnetometers**, which utilize optically pumped alkali atoms in a heated vapor cell to achieve ultrahigh magnetic-field sensitivity. Our recent work has demonstrated a cold-atom inertial sensing platform together with a SERF magnetometer operating in the SERF regime, achieving a magnetic-field sensitivity of approximately 10 fT/√Hz at 10 Hz and reliable detection of 10 pT magnetic pulses. Although based on different atomic platforms, these technologies are highly complementary for **GPS-denied navigation**, where cold-atom inertial sensors provide drift-free inertial measurements and SERF magnetometers enable magnetic fingerprint navigation using local geomagnetic signatures. This talk presents the operating principles, recent advances, and future prospects of atom-based quantum sensors, highlighting their potential for quantum-enabled navigation as well as applications in geophysics, space exploration, and biomagnetic imaging.

[Session D: Instruments]

라만 전이 기반 양자 제어를 위한 고성능 레이저 안정화 기술

김재완(명지대학교)

Abstract: 라만 전이는 원자의 양자상태를 정밀하게 제어하는 핵심 기술로, 정밀측정을 위한 원자간섭계와 최근 활발히 연구되고 있는 중성원자 양자컴퓨터 모두에서 널리 활용되고 있다. 두 연구 분야는 서로 다른 응용 목적을 가지지만, 높은 주파수 안정도와 낮은 위상잡음, 그리고 장시간 안정적으로 동작하는 레이저 시스템을 요구한다는 공통점을 가진다.

본 강연에서는 라만 전이 실험을 위한 레이저 주파수 안정화 기술과 실제 구현 방법을 소개한다. 원자 분광을 이용한 절대 주파수 기준을 비롯하여, 광학 표준 공진기(optical reference cavity)를 이용한 협대역 레이저 안정화와 Pound-Drever-Hall(PDH) 기법을 설명하고, 주파수 오프셋 잠금 (offset locking), 광학 위상고정루프(optical phase-locked loop, OPLL) 등 라만 레이저 시스템 구축에 필요한 핵심 기술들을 함께 다룬다. 또한 서보 제어, 광학계 설계, 진동 및 열적 잡음 억제 등 실제 실험에서 요구되는 기술적 고려사항과 구축 경험을 공유하고자 한다.

끝으로 이러한 레이저 안정화 기술이 원자간섭계와 중성원자 양자컴퓨터를 비롯한 다양한 라만 전이 기반 양자기술의 공통 실험 플랫폼을 형성한다는 점을 살펴보고, 그동안의 연구 경험을 바탕으로 차세대 양자기술을 위한 레이저 시스템의 발전 방향을 전망하고자 한다.

[Session D: Instruments]

Atomic Physics at an Accelerator Facility: Spectroscopy and Precision Measurements

Hoon Yu[1], Sung Jong Park[2], Jaehyun Song[2], Chaeyounf Lim and Jung Bog Kim[2]

1 Rep. of Korea Air Force Academy

2 Institute of Basic Science

Abstract: Accelerator facilities, especially RAON(Rare isotope Accelerator complex for ON-line) in Korea, provide unique opportunities for atomic physics with short-lived and rare isotopes that are unavailable in conventional laboratory environments. Atomic-physics techniques, particularly high-resolution laser spectroscopy and precision measurement, can make important contributions to the scientific use of rare-isotope accelerator facilities by measuring nuclear properties such as hyperfine constant, isotope shift, nuclear shift and etc, through atomic observables. In this presentation, we introduce our recent progress in accelerator-based atomic spectroscopy, including the successful spectroscopic measurement of sodium isotopes using the collinear laser spectroscopy system at RAON. This achievement demonstrates the feasibility of performing atomic spectroscopy with rare-isotope beams produced and delivered by a domestic accelerator facility. Ongoing efforts are focused on improving the spectral resolution, fluorescence-detection efficiency, and overall sensitivity of the system. We are also developing spectroscopic approaches for scientifically important atomic species, including aluminum isotopes and their nuclear isomers. These studies are expected to provide new opportunities for isotope- and isomer-selective detection and for investigating nuclear structure and related phenomena through atomic transitions. Beyond conventional fluorescence spectroscopy, our long-term plan aims to expand toward laser cooling and trapping of rare atoms, ion-detection-based spectroscopy, nuclear polarization and ultimately quantum-degenerate systems such as Bose–Einstein condensates of rare atomic species. Through these efforts, we aim to demonstrate that atomic physics can play an essential role in extending the scientific capabilities and impact of accelerator facilities.

[Session E: Cold Atoms and Molecules]

Neutral-Atom Quantum Optimization

안재욱(KAIST)

Abstract: Whether neutral-atom quantum optimization protocols exhibit genuine concentration toward low-energy solution structure remains an open question [1]. Here, we introduce a shots-to-approximate-solution metric and evaluate it using post-processed outputs modeled by a degeneracy-weighted shell distribution governed by a single effective parameter that quantifies concentration toward near-optimal independent sets [2].To extract the genuine concentration effect in the quantum data, we apply identical post-processing to both experimental bit-strings and randomly generated bit-strings with matched excitation density, thereby constructing an excitation-matched random baseline. Experiments on programmable Rydberg-atom arrays with system sizes up to 125 sites show that quantum annealing consistently exceeds the random baseline, demonstrating enhanced concentration toward low-energy solution structure beyond what can be attributed solely to excitation density. The results further reveal two distinct target-dependent regimes. For near-exact targets with ~1, the required shot count grows exponentially with system size and is reduced at the same exponential level by quantum annealing within the shell-model description. By contrast, for relaxed targets, the shot cost becomes effectively constant, and the corresponding quantum enhancement diminishes\new{, with the classical post-processing heuristic alone reaching the target in order-unity attempts}. Together, these results establish an operational method for quantifying quantum optimization performance and clarify the regimes in which structural concentration yields m easurable reductions in shot cost.

[1] M. P. Soegianto et al., "Neutral-atom graph programming for combinatorial optimization problems: from hardware-native maximum independent set to Sudoku," preprint (2026)

[2] Junwoo Jung et al., "Shots-to-Approximate-Solution Scaling in Neutral-Atom Quantum Optimization," preprint (2026).

[Session E: Cold Atoms and Molecules]

Quantum science with ultracold polar molecules

박지우(POSTECH)

Abstract: Ultracold polar molecules, with their rich internal structure and strong long-range dipolar interactions, offer a highly programmable and scalable platform for quantum science. This talk will review recent experimental advances in creating ultracold gases of polar molecules, including their nano-Kelvin assembly and direct evaporative cooling into the quantum regime. These developments pave the way for a wide range of applications, such as in quantum many-body research, including the quantum simulation of extended Hubbard models, precision quantum chemistry, and the realization of molecular qubits for stable quantum information processing. Ultracold polar molecules represent a cutting-edge platform for exploring complex quantum systems and advancing molecular control.

[Session E: Cold Atoms and Molecules]

Spin turbulence in quantum fluids: from chaotic spin dynamics to turbulent transport

신용일(서울대학교)

Abstract: Spinor Bose–Einstein condensates provide a unique platform for exploring nonequilibrium quantum fluids with internal spin degrees of freedom. In these systems, turbulence can arise not only from nonlinear flow dynamics and quantized vortices but also from the complex evolution of spin textures, giving rise to a distinct form of quantum turbulence known as spin turbulence. In this talk, I will present our experimental studies of spin turbulence in antiferromagnetic spin-1 Bose–Einstein condensates. Using resonant radio-frequency driving, we generate a stationary turbulent state sustained by chaotic spin dynamics, revealing a connection between microscopic spin chaos and macroscopic turbulent behavior [1,2]. To explore whether spin turbulence exhibits universal features analogous to those of conventional turbulence, we investigate the spectral dynamics of turbulent spin excitations. Recent measurements reveal a robust power-law scaling in the spin-interaction-energy spectrum over an extended range of length scales [3]. Furthermore, the spectral evolution of freely decaying turbulence provides evidence for a direct cascade of spin-interaction energy, providing new insight into energy-transfer processes in spinor quantum fluids. I will also discuss recent observations of enhanced damping of collective excitations in turbulent condensates [4]. The excess dissipation can be characterized by an effective turbulent viscosity, suggesting the emergence of hydrodynamic transport beyond conventional thermal damping. Finally, I will discuss prospects for establishing a hydrodynamic description of spin turbulence and its broader connections to universal transport phenomena in nonequilibrium quantum matter.

[1] Hong *et al.*, Phys. Rev. A 108, 013318 (2023).
[2] Kim *et al.*, Phys. Rev. Research 6, L032030 (2024).
[3] Lee *et al.*, arXiv:2606.00766.
[4] Lee *et al.*, Phys. Rev. Lett. 136, 253402 (2026).

[Session E: Cold Atoms and Molecules]

Toward Yb quantum processors over 1000 qubits

송윤흥(KRISS)

Abstract: 중성원자 양자 시스템은 지난 10년간 급속한 발전을 거치면서 양자 컴퓨팅의 구현을 위한 가장 유망한 시스템들 중 하나로 떠오르고 있다. 그동안 수천 개의 원자 배열 형성, 99.9%에 근접한 2큐비트 게이트 신뢰도, 동적 재배열을 통한 전체 대 전체 연결성, 연속 원자 재보충 등을 달성하며 수천 큐비트 스케일의 양자 프로세서를 위한 기반이 등장했지만 아직 이를 통합한 1000 큐비트급 양자 프로세서의 구축은 진행 중인 상황이다. 이 발표에서는 2전자 에너지 구조와 핵스핀 1/2 큐비트를 토대로 빠른 발전을 하고 있는 이터븀 원자 배열의 기준으로 1000 큐비트급 양자 프로세서를 구현을 위해서 필요한 요소들을 살펴본다. 그리고 이를 위한 이터븀 단일 원자의 99.9% 이상의 고신뢰도·고생존율 이미징 및 마이크로초 스케일의 고속 이미징을 비롯한 KRISS의 연구를 소개한다.

[Poster Session]

Development of a High-Repetition-Rate Single-Zone 87Rb Atom Interferometer

이민환(전남대학교)

Abstract: We report the development of a high-repetition-rate single-zone ^{87}Rb atom interferometer for precision inertial sensing. Cold ^{87}Rb atoms are prepared in an ultra-high-vacuum chamber using a magneto-optical trap followed by polarization-gradient cooling. To achieve rapid cyclic operation, the experimental sequence was optimized so that atom trapping, cooling, state preparation, Raman interferometry, and detection are performed within a single interaction zone. With this configuration, we demonstrated stable operation at a repetition rate of 20 Hz.

A capture–recapture scheme was implemented to increase the atom number available in each cycle and improve the effective loading rate. Internal-state preparation was optimized using optical pumping, and Raman $\pi/2$–π–$\pi/2$ pulses were applied to realize atom-interferometric measurements. The observed interference fringes demonstrate the feasibility of compact, high-repetition-rate atom interferometry for future quantum inertial sensing applications.

[Poster Session]

Performance characterization of an atom spin gyroscope

임신혁(ADD)

Abstract: We present the development and performance characterization of an atom spin gyroscope (ASG). The ASG has a compact physics package with a volume of 93 cc and a power consumption of 4.3 W. The Rb-Xe gas cell, with a 7.5 mm cubic geometry, was centered within a two-layer magnetic shield and surrounded by a coil system based on a flexible printed circuit board to generate a uniform magnetic field. Two distributed Bragg reflector lasers provided the pump and probe beams, and Xe spin precession was optically detected via Faraday rotation. The signal-processing system, implemented using a digital signal processor and a field-programmable gate array, generates the 131Xe phase-tracking gyroscope output at 500 Hz. The quantization-axis magnetic field was digitally stabilized using feedback from the combined 129Xe and 131Xe lock-in outputs. Allan deviation analysis showed an angle random walk of 0.005 deg/√h and a bias instability of 0.005 deg/h. The ASG exhibited a scale factor of 0.9516(26) and a full-scale rate of 300 deg/s.

[Poster Session]

All-optical pulsed rubidium atomic magnetometer for magnetic anomaly mapping of subsurface transportation infrastructure

Hyeonjae Kim(ADD)

Abstract: Optically pumped magnetometers exploit the collective spin dynamics of alkali-vapor ensembles to achieve high sensitivity in compact sensor platforms, enabling applications in biomagnetic sensing, magnetic navigation, and magnetic surveys. In this study, we demonstrate an all-optical pulsed rubidium atomic magnetometer for magnetic anomaly mapping of subsurface transportation infrastructure. The optically pumped rubidium atomic magnetometer employs laser mode hopping in a single-beam configuration to perform sequential optical pumping and off-resonant probing for free induction decay readout. During the probing period, the total scalar magnetic field is determined from the Larmor frequency of the rubidium spin precession. The magnetometer was mounted on a drone platform and used for magnetic-field surveys over the Boryeong undersea tunnel at flight altitudes of 50, 100, and 150 m. The residual magnetic anomaly maps showed an elongated anomaly pattern near the mapped tunnel location. Line-profile analysis quantified the altitude dependence of the anomaly amplitude and spatial width. Magnetic anomaly measurements over an underground high-speed railway in Sejong are also presented as a second field demonstration.

[Poster Session]

Miniaturization of Atomic Vapor Cells via Silicon-Glass Anodic Bonding

Jihwan Kim(ADD)

Abstract: The miniaturization of atomic vapor cells is essential for realizing compact, low-power, and portable quantum sensing devices. In this work, we demonstrate a miniaturized atomic vapor cell fabricated by anodically bonding a glass cell onto a silicon chip featuring integrated micro-heaters and temperature sensors. Rubidium was encapsulated inside the cell along with 250 Torr of nitrogen buffer gas. By controlling the cell temperature via the integrated heater, we successfully performed optical spectroscopy of the Rb atomic vapor with the 250 Torr buffer gas. Furthermore, the fabricated cell was experimentally evaluated and tested as a magnetic field sensor.

[Poster Session]

Hyperfine structure characterization and optical cycling enhancement in fermionic 25MgF molecules

임동규(고려대학교)

Abstract: Ultracold diatomic molecules such as alkiline-earth monofluorides or bi-alkali Feshbach molecules, have been suggested as a versatile quantum platform due to their long-range dipole-dipole interaction and long coherence time. Among alkaline-earth monofluorides, Magnesium monofluoride (MgF) is particularly promising for direct laser cooling and magneto-optical trapping due to its low mass and strong ultraviolet transition, which together enable a high photon scattering rate and large recoil velocity for fast deceleration. Especially, the fermionic isotopologue 25MgF holds unique potential for exploring Pauli exclusion effects in ultracold collisions and realizing degenerate, strongly interacting Fermi gases. However, establishing an effective optical cycling scheme for 25MgF is challenging. Unlike its bosonic isotopologues where the Mg nuclear spin is zero, 25Mg possesses a nuclear spin of I = 5/2. The coupling of this Mg nuclear spin with the electron spin as well as the rotational angular momentum N and the nuclear spin of F introduces a highly complex hyperfine structure manifold in both the ground and excited states. Precise spectroscopic characterization of this energy structure is a critical prerequisite for implementing an efficient optical cycling transition. In this work, we present high-resolution laser-induced fluorescence (LIF) spectroscopy of 25MgF. We experimentally resolve eight distinct spectra corresponding to the rotational quantum numbers N = 0, 1, 2 across the P, Q, R transitions. Furthermore, using the given spectra, we successfully demonstrated the optical cycling enhancement by applying an electro-optic modulator (EOM) to address multiple hyperfine transitions simultaneously. These results can provide the effective design optical cycling scheme for laser cooling and trapping of the 25MgF molecules.

[Poster Session]

Hybrid Oscillator–Qubit Metrology in a Trapped Ion

강지용(서울대학교)

Abstract: Trapped-ion systems offer coherent laser-driven coupling between internal spin states and quantized motion, providing a versatile platform for entangling gates, spin–boson simulations, and hybrid continuous-variable–discrete-variable quantum protocols. Here, we use spin-dependent control of two motional modes to realize hybrid spin–motion interferometry for sensing a bosonic phase difference. We generate hybrid spin–motion entangled states, including a hybrid entangled coherent state, where the two-mode coherent-states $|\alpha\rangle|0\rangle$ and $|0\rangle|\alpha\rangle$ are entangled with spin σ_x-eigenstates, and a hybrid NOON state constructed from the two-mode Fock-states $|N\rangle|0\rangle$ and $|0\rangle|N\rangle$. In this architecture, the phase difference accumulated between the two motional paths is mapped onto the spin degree of freedom and extracted using standard spin readout. We experimentally demonstrate this spin-readout-based bosonic phase-difference sensing protocol in a trapped-ion system and show phase sensitivity that approaches Heisenberg scaling as the coherent-state amplitude $|\alpha|$ or the Fock-state number N increases.

[Poster Session]

Progress Toward Longitudinal Laser Slowing of a Cryogenic MgF Beam

조영주(고려대학교)

Abstract: Magnesium monofluoride (MgF) is a highly promising candidate for direct laser cooling and slowing, owing to its highly diagonal Franck-Condon factors, ultraviolet transitions, and relatively light mass. However, achieving a closed optical cycling transition in diatomic molecules is challenging due to their complex ro-vibrational structures. While strict closure is unachievable for vibrational states without additional repump lasers, utilizing rotational selection rules allows for quasi-closed optical cycling.

Building upon our recent optimization of the MgF optical cycling scheme, where we addressed hyperfine structures and dark Zeeman states to maximize photon scattering, we extend our study toward the longitudinal laser slowing of an MgF cryogenic buffer-gas beam. We report on our ongoing experimental progress, focusing on the implementation of the slowing laser scheme and the systematic characterization of the initial molecular beam.

Specifically, the longitudinal velocity of our cryogenic molecular beam was measured to be centered at 160 m/s. Furthermore, we investigated transverse optical pumping by driving main slowing transition (A(v=0,J=1/2) <- X(v=0, N=1)) to transfer molecules into the X(v=1, N=1) state. Crucially this measurement confirmed the absence of unintended leakage paths, verifying the robustness of our optical cycling scheme. These combined characterization efforts provide practical guidance and establish the necessary prerequisites for the upcoming demonstration of longitudinal laser slowing and a magneto-optical trap for MgF.

[Poster Session]

Characterization and mitigation of pairwise-correlated errors on ^{87}Rb neutral atom analog computing platform

박주영(JuYoung Park)(KAIST)

Abstract: Arrays of neutral atoms with strong interactions mediated by Rydberg states have become a promising platform for practical quantum computing. Their capabilities, however, have largely been quantified by single- and few-atom figures of merit that are implicitly assumed to scale across the entire array. As array sizes and circuit depths grow, the assumption is increasingly challenged: a global excitation field imprints common laser intensity and phase noisy on all atoms, the van der Waals coupling connects sites beyond the strong Rydberg interaction regime, finite thermal motion fluctuates interatom distances, and detection crosstalk adds further spatially and temporally correlated deviations from the target evolution. Such imperfections increasingly limit both the fidelity of quantum computing and the assessment of quantum advantage, which is up to this day have partially dealt into consideration. In this work, we focus on the characterization and mitigation of pairwise-correlated errors on experimental ^{87}Rb neutral atom platform for quantum computing. Spatial and temporal correlation structure of errors are identified, to their microscopic origin. Mitigation strategies are devised to be implemented on relatively small scale and expected to be extended to large scale general array of atoms. Preliminary results show that the microscopic error channel is identifiable as pairwise nn Lindblad dissipation channel with <2 rad/us at maximum near strong Rydberg interaction threshold $R_b \equiv (C_6/\Omega)^{1/6}$ where C_6 is van der Waals interaction coefficient and Ω is Rabi frequency of Rydberg excitation beam, which is available to be mitigated by geometric deformation of the original array of atoms and/or optimal pulse control.

[Poster Session]

Design of a Continuous Atomic Beam Source Combining 2D MOT and 3D PGC for Quantum Inertial Sensors

곽민재(전남대학교)

Abstract: We present the design of a continuous atomic beam source for atom-interferometric quantum inertial sensors. Atom interferometers provide exceptionally precise measurements of acceleration and rotation by exploiting the quantum superposition and interference of matter waves. However, conventional pulsed atom interferometers suffer from dead time associated with cooling and detection cycles, which limits the measurement bandwidth and introduces aliasing noise.

To overcome these limitations, we propose an architecture that combines a two-dimensional magneto-optical trap (2D MOT) with three-dimensional polarization-gradient cooling (3D PGC). In the proposed system, a continuous atomic beam generated in the 2D MOT is transferred into the 3D PGC region, enabling continuous delivery of ultracold atoms while mitigating dead-time effects and improving measurement stability.

The system is designed with optimized laser parameters and magnetic-field configurations to maintain a high atomic flux while substantially reducing the transverse temperature of the atomic beam. This design provides a practical pathway toward stable continuous cold-atom sources and establishes a foundation for next-generation quantum gravimeters and quantum inertial sensors based on continuous atom interferometry.

[Poster Session]

Toward Laser Cooling of Carbon

이용웅(고려대학교)

Abstract: Neutral carbon plays an important role in chemistry and astrophysics, but it has not yet been laser cooled. The main problem is that the closed cycling transitions from the ground state lie in the vacuum ultraviolet (VUV, 166 nm) region, making a conventional cooling scheme technically demanding. To circumvent this limitation, we propose an alternative route that is based on long-lived metastable states 1D2 and 1S0. The scheme uses the 1D2 and 1S0 states as the two lower states of a Λ-type optical cycle through the 1Po1 state. This Λ-type optical cycle enables laser cooling without requiring direct access to the 166 nm transition. Carbon atoms are excited from the 1S0 to the 1Po1 state using a 247.8 nm laser, followed by spontaneous decay to both the 1S0 and 1D2 states. Population in the metastable 1D2 state is repumped to 1Po1 using a 193.1 nm laser.

In this study, we propose a Λ-type laser cooling scheme for neutral carbon. Carbon atoms are produced by 266 nm laser ablation of a highly oriented pyrolytic graphite (HOPG) target, then thermalized in a cryogenic helium buffer-gas cell to form a cold, slow atomic beam. Cold gas-phase carbon atoms will be generated using a cryogenic buffer-gas beam source. We are investigating whether a sufficient metastable-state population can survive collisional thermalization and extraction from the buffer-gas cell.

The principal technical challenges are the generation of high-power continuous-wave radiation at 193.1 nm and efficient momentum transfer within the available photon budget. We have designed a nonlinear frequency-conversion architecture for generating the 193.1 nm light and performed numerical simulations of the Λ-type cooling dynamics, including optical pumping, branching losses, and the finite interaction time of the buffer-gas beam. Numerical simulations predict that the proposed scheme provides sufficient radiative force for laser slowing under realistic experimental conditions.

[Poster Session]

Development of Ytterbium Optical Lattice Clocks at KRISS: System Overview, Ongoing Projects, and Applications

이현경(한국표준과학연구원)

Abstract: The advent of optical frequency combs has enabled the rapid development of optical clocks, which now achieve relative frequency uncertainties approximately two orders of magnitude lower than those of cesium primary standards. Consequently, international efforts are underway to redefine the SI second based on optical clocks around 2030.

At the Korea Research Institute of Standards and Science (KRISS), research on ytterbium (^{171}Yb) optical lattice clocks has been actively pursued to support the next generation of time and frequency metrology. Notably, the KRISS-Yb1 clock was officially recognized as the fifth optical clock in the world registered with the BIPM as a secondary frequency standard. It has been continuously contributing to Coordinated Universal Time (UTC) since 2021 and Korea′s national time scale UTC(KRIS) since 2022. Building on this foundation, we are currently developing next-generation Yb optical lattice clocks aimed at reducing the frequency uncertainty by approximately one order of magnitude.

In this poster, we present an overview of our Yb clock systems, ongoing research projects, and broader applications of optical lattice clocks as ultra-precise quantum sensors and quantum information processing platforms.

[Poster Session]

Highly Charged Ion Spectroscopy: Observation of Third-Harmonic Generation in X-ray Free Electron Laser at Pohang Accelerator Laboratory

박성남(KRISS)

Abstract: An electron beam ion trap (EBIT) is a device used to create and study highly charged ions (HCIs). Investigating HCIs typically requires photon sources in the X-ray regime, which is where accelerator-based light sources become relevant. Using the X-ray free-electron laser at the Pohang Accelerator Laboratory (PAL-XFEL), operating at a 60 Hz repetition rate, we conducted X-ray spectroscopy inside an ion trap. During this beamtime, we requested a fundamental photon energy of 3.1 keV; however, an unexpected two-line feature appeared on the silicon drift detector (SDD): a stronger line near 4.5 keV and a weaker line near 4.9 keV. This pattern is consistent with third-harmonic photons (3×3.1 keV ≈ 9.3 keV) exciting titanium — a constituent material of the EBIT drift-tube electrodes — producing Ti Kα (4.51 keV) and Kβ (4.93 keV) fluorescence, both of which require photon energies above the Ti K-edge (4.97 keV) to excite. The relative weakness of the Kβ line and the expected line spacing are both consistent with this assignment. In this poster, we present this observation as evidence of higher-harmonic content in the PAL-XFEL beam and discuss its implications.

[Poster Session]

Implementation and Performance Evaluation of a Rack-Mounted Testbed for a Field-Deployable Rubidium Atomic Clock

CHOI Soyeon(Korea Research Institute of Standards and Science(KRISS), University of Science and Technology(UST))

Abstract: Miniature atomic clocks are essential components of portable systems requiring precise time synchronization, including navigation, communication, and timing infrastructure. For field-deployable applications, in particular, characterizing the frequency dependence on parameters under constraints of limited spatial and thermal resources is a prerequisite for the design of a dedicated package. For this purpose, we implemented a rack-mounted testbed for a field-deployable rubidium atomic clock, enabling the investigation of various physical mechanisms affecting frequency shifts in an isolated environment.

The clock employs microwave-optical double resonance in a buffer-gas-filled rubidium vapor cell. The system consists of a laser source, a physics package, and electronic instrumentation. A compact Doppler-free saturated absorption spectroscopy setup is used to stabilize the laser frequency. The physics package incorporates a vapor cell, a microwave cavity, C-field coils, and magnetic shielding, while the electronic module generates and applies a microwave signal corresponding to the rubidium ground-state hyperfine transition.

Microwave detuning around the hyperfine resonance produces a double-resonance absorption signal in the transmitted laser intensity, from which an error signal is derived to stabilize the local oscillator. The clock frequency stability was evaluated relative to a hydrogen maser using the Allan deviation, with the fractional frequency stability reaching 6 × 10^(-14) at an averaging time of 1000 s. The measured performance confirms the successful operation of the rack-mounted testbed, supporting further investigation of frequency shifts in field-deployable rubidium atomic clocks.

[Poster Session]

Mitigating Measurement Noise in Fast Neutral Atom Quantum Experiments

배재익(KAIST/KRISS)

Abstract: Fast and reliable state measurement is a central bottleneck in scaling neutral atom quantum processors. Operating neutral atom processors in the fast measurement regime requires short imaging times, where readout uncertainty becomes non-negligible and can strongly impact downstream operations. We demonstrate that explicitly accounting for measurement noise substantially improves system performance under fast measurement conditions. In rearrangement, this leads to reduced atom shuttling and improved final array quality. In surface code simulations, we observe lower logical error rates and improved effective error thresholds under fixed hardware error budgets, even when measurement times are constrained to be short. By addressing the measurement bottleneck, this work provides insight into how fast experimental cycles can be made compatible with scalable quantum error correction.

[Poster Session]

Design and Construction of a Quantum Processor with Two-Dimensional Ion Crystals

Junhee Cho(Institute for Basic Science)

Abstract: Trapped-ion systems are promising platforms for quantum simulation because of their long coherence times, high-fidelity state preparation and readout, and tunable long-range interactions mediated by collective ion motion. Compared with linear ion chains, two-dimensional ion crystals provide a more favorable route toward larger ion systems and offer opportunities to investigate topological phenomena and quantum many-body physics in two dimensions.

This work describes the ongoing development of a fully programmable platform for two-dimensional trapped-ion crystals with individual-ion control. The platform incorporates three major technical improvements: an extreme-high-vacuum environment, suppression of electrical noise, and a scalable individual-addressing optical system with reduced beam-position fluctuations.

The vacuum system is designed for extreme-high-vacuum operation using a heat-treated chamber and low-outgassing components, with its expected performance evaluated through numerical simulations. By reducing collisions between trapped ions and residual gas molecules, the system is expected to support long ion-storage lifetimes and stable operation of large ion crystals. Dedicated filter boards are integrated with the DC control electronics to suppress capacitive RF pickup and electric-field noise, which can lead to excess micromotion and fluctuations of the trapping fields near the electrodes.

For site-resolved optical control, the system employs a hybrid spatial-light-modulator–digital-micromirror-device architecture. This approach is designed to overcome the limited scalability of multichannel acousto-optic modulator and acousto-optic deflector systems for two-dimensional addressing, as well as the relatively slow update rates of conventional spatial light modulators. By combining programmable beam shaping with fast optical modulation, the platform is expected to enable scalable, high-fidelity site-resolved operations for quantum computation and quantum simulation beyond the capabilities of classical computation.

[Poster Session]

Toward Experimental Validation of a 137Ba+ 5D3/2 Metastable-State Qubit

유재훈(서울대학교)

Abstract: We investigate a qubit encoded in the hyperfine-Zeeman manifold of the 5D3/2 state of 137Ba+, with state preparation and fluorescence detection based on the standard 493 nm and 650 nm transition network. Refined simulations indicate that the achievable initialization and detection fidelities may be limited to approximately 95% under the currently considered conditions, motivating direct experimental validation of the proposed scheme. As a first step, we are developing an experimental platform for loading and trapping 137Ba+. We present the qubit concept, the proposed state-preparation and detection protocol, and progress toward stable ion trapping and experimental initialization and detection of the 5D3/2 state.

[Poster Session]

Heading Error Correction using IMU in Drone-based Magnetic Survery with Optically Pumped Atomic Magnetometer

김상우(국방과학연구소 (ADD))

Abstract: In this study, we developed a drone-borne magnetic survey system based on a single-beam optically pumped atomic magnetometer (OPAM) and implemented an IMU-aided compensation of heading-dependent magnetic errors. The OPAM provides a low-noise scalar measurement through optical pumping of atomic spins; however, in airborne operation the platform's own magnetic field introduces a systematic error that varies with the heading angle. To compensate for this error, we applied a Tolles–Lawson (T-L) model in which the field direction cosines are obtained by combining IMU attitude data with the International Geomagnetic Reference Field (IGRF). In boustrophedon surveys, however, the heading is confined to 0° and 180°, which renders the T-L design matrix rank-deficient; the heading error surviving this compensation left residual corrugation in the magnetic map. To resolve this, we constructed the forward- and backward-leg maps separately and estimated the error field from their difference, exploiting the fact that the direction-cosine projection of the permanent-field component reverses sign between legs. This forward–backward differencing recovered the corrected field and suppressed the corrugation that the rank-deficient T-L solution alone could not remove, even when dedicated calibration flights were unavailable.

[Poster Session]

Photonic grating chip assisted measurement of the 88Sr 461-nm transition

이재환(한국과학기술원)

Abstract: We demonstrate photonic grating chip assisted spectroscopy of the 88Sr 461-nm transition in a compact atomic apparatus. The in-vacuum grating chip provides a stable counter-propagating probe geometry for spatially resolved fluorescence spectroscopy of a thermal atomic beam and simultaneously serves as the optical platform for a two-dimensional grating magneto-optical trap. The transition frequency is independently inferred from pixel-resolved multi-isotope spectra and slow-atom velocity measurements. Four datasets obtained by the two approaches agree within their uncertainties, yielding 650.503815(5)THz. These results highlight photonic grating platforms as versatile interfaces for compact strontium spectroscopy and laser-cooling systems.

[Poster Session]

Observation of Scaling Behavior of Spin Turbulence in Spinor Bose-Einstein Condensates

이정훈(SNU)

Abstract: In this poster, we present the observation of scaling behaviors in spin turbulence within a spinor Bose-Einstein condensate (BEC). An antiferromagnetic spin-1 BEC is prepared in an oblate optical dipole trap, featuring effectively two dimensional spin excitations. By driving chaotic spin dynamics in this spin-1 BEC, complex spin textures are generated accompanied by turbulent mass flow. Through in-situ spin-selective imaging of these textures, we obtain the spin energy power spectrum. The spectrum exhibits two distinct scaling regions characterized by exponents of -1 and -7/3. These scaling laws are distinct from those of the kinetic energy spectrum in conventional turbulence and are well-described by the spin hydrodynamic equations of the antiferromagnetic spin-1 BEC. Furthermore, this scaling behavior appears universal even as the quadratic Zeeman energy, which determines the system′s nematic anisotropy, is varied.

[Poster Session]

Internal-Motional Coupling in Flying Rydberg Atom Collisions

황선화(KAIST)

Abstract: The frozen gas approximation has long enabled interacting ultracold atomic systems to be described by neglecting atomic motion. However, recent optical tweezer platforms have reached regimes where interaction-induced motion becomes dynamically relevant and strongly influences coherent many-body dynamics. Here, we experimentally investigate coupled internal and motional dynamics using controlled collisions between flying Rydberg atoms. By launching pairs of atoms with well-defined trajectories, we access interaction regimes where Rydberg forces generate strong coupling between atomic qubit and motional degrees of freedom.

In the weak interaction regime, Ramsey interferometry reveals coherence suppression arising from conditional atomic motion. Depending on the two-qubit state, atoms experience different interaction forces and follow distinct motional trajectories, reducing the overlap between conditional motional wavepackets and consequently the coherence of the internal-state subsystem. In the strong interaction regime, the same coupling produces state-dependent forces that drive measurable motional wavepacket splitting, directly observed through spatially resolved recapture measurements. Together, these results provide a direct experimental observation of coupled internal and motional dynamics in interacting Rydberg atoms and establish a regime beyond the frozen gas approximation where atomic motion plays an essential role in coherent quantum dynamics.

[Poster Session]

Quantum Control of a Single 87Rb Atom in an Optical Tweezer via D1 Electromagnetically Induced Transparency

이대범(고려대학교)

Abstract: Compared to D2 transition, D1 transition of alkali atoms provides a route to high-fidelity quantum control of single atoms due to its simpler energy-level structure while maintaining a comparable scattering force. Several experiments relevant to Rydberg-atom quantum processors have exploited the D1 transition for single-qubit gates, Raman sideband cooling, and Λ-gray molasses. Here we present cooling of a single 87Rb atom in an optical tweezer via D1 electromagnetically induced transparency (EIT) in an optical tweezer, previously demonstrated based on the D2 transition [1,2]. The EIT cooling is implemented in a D1 -type system formed by the magnetic sublevels of the F=2 -> F′=2 transition. After 10 ms polarization-gradient cooling, our preliminary results show a reduction in temperature from 53(1) uK to 27(1) uK, as determined by release-and-recapture measurements.

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[Poster Session]

Creation of a dual species BEC of Rb and Yb

박준영(서울대학교)

Abstract: Rubidium is one of the most widely used alkali-metal species in ultracold-atom experiments, owing to its experimentally accessible optical transitions. Ytterbium, an alkaline-earth-like atom, has also attracted considerable interest for applications in optical atomic clocks, trapped-ion systems, and studies of SU((N))-symmetric fermionic many-body physics. Ytterbium has several stable isotopes, and the interspecies interaction between Rb and Yb varies strongly with the Yb isotope.

Among these mixtures, 87Rb-174Yb exhibits a particularly strong repulsive interspecies interaction, which makes the realization of a quantum-degenerate mixture challenging. Despite this difficulty, we have produced a dual-species Bose–Einstein condensate of 87Rb and 174Yb by precisely controlling the vertical separation between the two species during evaporation. After independently forming the two condensates, we merge them to create an interacting dual-species BEC mixture. In this system, we observe in situ phase separation as well as strong three-body loss.

[Poster Session]

Progress toward a dual-species Ytterbium quantum processor: From narrow-line cooling to bichromatic triple-magic trapping

윤은식(고려대학교)

Abstract: Ytterbium (Yb) has emerged as a premier platform for quantum information science, offering a unique combination of narrow intercombination transitions ($^1S_0$–$^3P_1$, $^1S_0$–$^3P_0$), long-lived nuclear spin coherence, and low magnetic field sensitivity. Its diverse isotopic landscape allows both bosonic and fermionic qubit encodings, enabling applications in quantum simulation and precision metrology. We report experimental progress toward a ^{171}Yb quantum computing platform. For robust cooling and trapping, the 399 nm laser is frequency-stabilized via modulation transfer spectroscopy (MTS) using a Yb hollow cathode lamp, while the 556 nm narrow-line cooling transition is referenced to a molecular iodine frequency standard.

For high-fidelity two-qubit gates mediated by Rydberg blockade, the tweezer potential must simultaneously trap the ground, metastable, and Rydberg states without differential light shifts — a condition that a single trapping wavelength cannot generally satisfy, since at most two of the three states can be made magic at once. We theoretically propose a bichromatic optical tweezer (λ_1 = 532.0 nm, λ_2 = 552.6 nm) with tunable intensity ratio $\eta = I_2/I_1$ and relative polarization angle θ. By minimizing a light-shift cost function over (η, θ), we calculate a "magic valley" — a near-triple-magic trapping condition for the $^3P_0$, $^3P_2$, and Rydberg (6sns $^3S_1$) states — at $\eta \approx 0.05$, $\theta = 90°$, and trap depth $U \approx 1.2$ mK, with the predicted residual differential shift suppressed to $\delta\nu < 10$ kHz across all three states.

On the experimental side, we collect atoms in a blue (399 nm) 2D-MOT and transfer them via a green (555.6 nm) push beam into a differentially-pumped science cell, where a narrow-line 3D-MOT is formed for loading a 2D optical tweezer array via a high-numerical-aperture objective. The 2D-MOT has been achieved, and the green-MOT transfer is currently underway. We outline prospects for integrating this magic-trapping scheme with Rydberg spectroscopy toward the fault-tolerant gate regime.

[Poster Session]

Progress toward Spin-Resolved Detection of SU(N) Fermions

강광휘(KAIST)

Abstract: We aim to explore SU(N=6) quantum many-body physics using fermionic 173Yb. An SU(N)-symmetric system has identical interaction strengths between distinguishable spin components. We currently trap approximately 10^7 atoms with a loading time of 30 s, as measured by absorption imaging. We use a Zeeman slower at 399 nm and a three-dimensional magneto-optical trap (MOT) at 556 nm. For spin-resolved detection, we plan to perform state-selective imaging with laser cooling on the 1S0 F=5/2 → 3P1 F′=7/2 transition. Long-term laser frequency stability is essential because the 556 nm transition used for optical pumping and imaging has a narrow natural linewidth of 182 kHz. We therefore compensate for the long-term drift of the ULE-cavity-locked laser using a Doppler-free dispersive signal obtained through modulation-free molecular iodine birefringence spectroscopy.

[Poster Session]

Now I am become Atom, the destroyer of hidden threats: A <25 g ^{87}Rb Free-Induction-Decay Scalar Magnetometer Enabling Unshielded Outdoor Magnetic Anomaly Detection

이헌식((주)오에이큐)

Abstract: Optically pumped atomic magnetometers (OPAMs) can achieve sub-femtotesla sensitivity under laboratory conditions. Extending this performance to unshielded outdoor environments, however, remains challenging because measurements must be performed on moving platforms in the Earth's magnetic field. Here we present a compact ^{87}Rb free-induction-decay scalar magnetometer designed for outdoor operation. A single distributed-Bragg-reflector laser provides both optical pumping and probing, eliminating the modulators and coils required in conventional designs and reducing the sensor head to 27 mL and 24.8 g. Mounted on a small multirotor UAV and interfaced with a commercial off-the-shelf FPGA readout board, the sensor resolves the magnetic anomalies of both an anti-tank mine and a vehicle. Despite differing by approximately three orders of magnitude in magnetic moment, the measured signals follow a common $1/r^3$ dependence over two decades of distance, confirming that the measurement chain preserves signal scaling in the field. These results demonstrate the feasibility of compact atomic magnetometers for unshielded outdoor magnetic anomaly detection.

[Poster Session]

Development of Drone-Deployable ^{87}Rb Atomic Magnetometer Prototypes for Industrial Applications

이현빈((주)오에이큐)

Abstract: We developed ^{87}Rb atomic magnetometer prototypes across three versions aimed at industrializing optically pumped magnetometry for drone-based (airborne) platforms. Each version was driven and read out using a commercial-off-the-shelf (COTS) data acquisition (DAQ) system. The first version employed a DBR laser in an all-optical Bell-Bloom-type sensor head (121 × 30 × 30 mm, 175 g) and extracted the magnetic field via lock-in detection. The second version retained the same all-optical sensor head design but instead acquired the atomic free-induction-decay (FID) signal at a 1 kHz bandwidth and computed the magnetic field using a zero-crossing algorithm. This version also miniaturized the sensor head to 21 × 26 × 50 mm and 25 g, roughly a fourfold reduction in volume and a sevenfold reduction in weight relative to the first version. The third version adopted a different physical design philosophy, replacing the DBR laser with a VCSEL that offers better cost-effectiveness and accessibility. It used an Mz-configuration sensor head with Helmholtz-coil biasing, at a size comparable to the second version, and likewise computed the magnetic field from FID signals via zero-crossing detection. Across these three development stages, the sensor head evolved from an initial all-optical design toward a more compact and cost-effective platform, while consistently maintaining a noise floor of approximately 20 pT in a shielded environment. Each version was fabricated within dimensions and weight suitable for airborne deployment and confirmed to operate reliably under real-world field conditions, establishing a quantum sensor hardware foundation for practical, industrialized magnetic sensing platforms.

[Poster Session]

Fabrication of Alkali Vapor Cells and Estimation of Buffer-Gas Pressure from Calibrated Absorption Spectra

김준영((주)오에이큐)

Abstract: This study presents the fabrication process of alkali vapor cells, key components of chip-scale atomic clocks and quantum sensors, alongside a spectroscopic analysis pipeline for optically evaluating the internal buffer-gas pressure. We describe an in-house fabrication procedure that utilizes a vacuum and gas-handling system to inject and seal ^{87}Rb and ^{133}Cs atoms with N_2 and He buffer gases at targeted ratios. To diagnose the fabricated cells, we apply a Python-based analysis workflow using a single scanned-laser transmission setup. The pipeline calibrates the frequency axis against the hyperfine comb of an unperturbed reference cell, normalizes the target spectrum by the reference to eliminate power ramps and etalon fringes, and fits a fixed-structure hyperfine Voigt comb to derive the collisional shift and Lorentzian broadening. Demonstrated on ^{87}Rb and ^{133}Cs cells filled with 100–650 Torr of N_2, the estimated pressures show high agreement with the nominal values. Furthermore, by utilizing the opposite signs of the shift coefficients for N_2 and He, we successfully isolate the partial pressures in two-gas mixture cells. These results establish a complete workflow from the fabrication of atomic vapor cells to the optical verification of their internal gas pressures.

[Poster Session]

경로를 재탐색합니다, 위성 없이. 양자센서 기반 지구물리 지도 제작과 무(無)-GPS 항법

이덕영((주)오에이큐)

Abstract: GNSS 거부 환경에서 관성항법장치(INS)의 누적 오차를 억제하기 위한 지구물리 지도 정합 항법을 연구하였다. 본 포스터에서는 자기이상 단독 항법에서 중력·자기 이중 지도 융합을 거쳐 자체 실측 자료 검증에 이르는 연구 과정을 제시한다.

우리나라 자기이상지도와 양자 자력계를 확장칼만필터로 결합하여 전술급 및 항법급 INS의 장기 오차 보정 가능성을 확인하였다. 그러나 지도 해상도와 실제 자기보상 잔차를 적용하면, 전술급 IMU에서 인접 등고선으로 오정합되는 false-lock과 필터 발산이 나타났다. 이에 상관성이 낮은 중력이상과 자기이상 지도를 융합한 결과, 단일 자기지도 항법의 실패를 억제하고 RMS 오차를 86–90% 감소시켰다.

마지막으로 자체 제작 원자 기반 양자 자력계를 무인기에 탑재하여 자기이상지도를 구축하고, RTK 기준해를 이용한 replay 방식으로 항법 성능을 평가하였다. 센서 제작부터 탐사, 지도화, 항법 검증까지의 수직 통합 결과를 바탕으로 양자 중력·자기 복합항법의 적용 가능성을 논의한다.

[Poster Session]

Quantum many-body simulation and computing with ultracold polar molecules

Donghyun Kwon, Shinwoo Lee(Department of Physics, POSTECH)

Abstract: Ultracold dipolar molecules, with their strong long-range and anisotropic interactions, offer promising opportunities for quantum simulation and quantum information processing. We report progress on two complementary platforms: an ultracold NaK experiment for quantum many-body physics and a KCs optical tweezer experiment for gate-based quantum computing. The NaK apparatus produces ultracold fermionic 23Na40K and bosonic 23Na41K Feshbach molecules by radio-frequency association, which can subsequently be transferred to their rovibrational ground state via stimulated Raman adiabatic passage (STIRAP). Incorporating a high-resolution microscope objective will enable spatially resolved studies of exotic dipolar many-body phenomena, including paired superfluidity and extended Hubbard physics. In parallel, we are developing a dual-species 39K-133Cs optical tweezer apparatus for assembling dipolar KCs molecules. This platform aims at the deterministic preparation of K-Cs atoms pairs, their coherent association into ground-state KCs molecular qubits, and high-fidelity control and entangling operations between individual molecules. Together, these platforms address complementary regimes ranging from strongly correlated dipolar quantum matter to programmable molecular-qubit arrays.

[Poster Session]

Chip-cell-based ^{87}Rb two-photon spectroscopy module with T-shaped geometry for long-term operational stability

박경빈(한국과학기술원(KAIST))

Abstract: In heated microfabricated vapor cells, metallic rubidium condenses at the coldest interior surface, and droplets on the optical windows obstruct the interrogation path, limiting the operating lifetime of chip-scale optical frequency references. We report a ^{87}Rb two-photon spectroscopy module built around a T-shaped chip cell that removes this limitation: a stem protrudes beyond the resistive heater, and finite-element simulation shows that with the interrogation channel at 105 °C the stem settles near 100 °C, placing the coldest interior point outside the optical volume. After more than one month of continuous heated operation the rubidium deposit remains confined to the stem while the interrogation window stays clear. The $5S_{1/2} \rightarrow 5D_{5/2}$ transition at 778 nm is interrogated in retro-reflection from a dichroic coating on the cell's rear face, which serves both as the Doppler-free retro-reflector and as the first stage of 420 nm fluorescence pick-off, removing the need for an interference filter. Sub-Doppler spectra are resolved for all four ground-state hyperfine groups of natural-abundance rubidium; Voigt fitting of the ^{87}Rb $F=2 \rightarrow F'=4$ component gives a total linewidth of 1.11 MHz (Lorentzian 0.72 MHz, Gaussian 0.64 MHz).

[Poster Session]

AESPA — Atomic-magnetometer Era: Sensing, Positioning & Anomaly-detection

최민석((주)오에이큐)

Abstract: Optically pumped atomic magnetometers (OPAMs) reach high magnetic sensitivity using optical pumping, atomic vapor cells, and precision spectroscopy, techniques native to atomic and molecular physics. Yet these competencies are seldom regarded as industrial assets, and atomic physics is often seen as far from application. Against this perception, this poster organizes the industrial use of OPAMs into two operating regimes — zero-field and total-field — and shows how each answers a distinct class of real-world problems. In the zero-field regime, near-zero-field SERF operation within magnetic shielding delivers the extreme sensitivity needed for biomagnetism: non-cryogenic OPAM-based magnetoencephalography has entered clinical evaluation for epilepsy and neurodegenerative disease. In the total-field (scalar) regime, operation within the Earth's field on unshielded, moving and airborne platforms enables magnetic anomaly detection, resource and geophysical survey, and magnetic navigation in GPS-denied environments, where the Earth's field itself serves as an unspoofable reference. Already commercial in both regimes, OPAMs nonetheless remain a nascent industry, one in which the Korean firm OAQ is now taking part. This poster asks where the industrialization of quantum technology stands, and why its advance is needed now.

[Poster Session]

Molecular dynamics in an optical partial standing wave

Eunkang Kim (UNIST)

Abstract: Optical lattices are widely used to manipulate atoms and molecules in both cold-atom and molecular-beam experiments. For nonspherical molecules, however, the interaction with an optical lattice depends not only on the spatial modulation of the laser field but also on intensity-dependent molecular alignment. An ideal optical standing wave (SW), formed by two counterpropagating laser beams of equal intensity, has zero-intensity nodes. Once its modulation amplitude is fixed, the average intensity—and therefore the degree of molecular alignment—cannot be independently controlled.

Here, we propose using a partial standing wave (PSW), formed by two counterpropagating beams of unequal intensities. Unlike an ideal SW, a PSW has nonzero intensity at its nodes, allowing the average intensity to be varied independently of the lattice modulation amplitude. This intensity imbalance therefore provides an additional control parameter for tuning molecular alignment and the resulting interaction between nonspherical molecules and the optical field.

First, we theoretically calculate the laser-intensity-dependent alignment of linear molecules in different rotational states and examine how this alignment modifies the optical potentials produced by SWs and PSWs. We then experimentally investigate the transverse dispersion of CS_2 molecules in a SW and PSW using a cold molecular beam, in which the population is confined to a small number of low-lying rotational states. A series of PSWs with increasing modulation amplitudes is generated by varying the intensity of one beam while keeping that of the counterpropagating beam fixed, and the resulting transverse velocity distributions are measured. Finally, we perform numerical trajectory simulations that incorporate the laser-intensity-dependent molecular alignment. The simulations quantitatively reproduce the measured velocity distributions and the intensity dependence of their characteristic parameters, while also revealing the phase-space dynamics of the molecular ensemble in the SW and PSW potentials.

This work establishes intensity imbalance in an optical lattice not as an experimental imperfection, but as a controllable parameter for independently tuning the average intensity and thereby tailoring molecular alignment and the dispersion dynamics of cold molecular beams.

[Poster Session]

Laser Resonance Chromatography on Lu+ ions

EunKang Kim (JGU)

Abstract: Optical spectroscopy of superheavy elements (SHEs) is extremely challenging because of their low production rates, short half-lives, and largely unknown atomic energy-level structures. SHEs are typically produced in complete-fusion reactions at rates of only a few atoms or ions at a time. Consequently, conventional optical spectroscopy techniques generally lack the sensitivity required for their investigation, motivating the development of new spectroscopic methods specifically designed for SHEs.

In this contribution, I introduce Laser Resonance Chromatography (LRC), a new technique developed to achieve the sensitivity required for optical spectroscopy of SHE ions. I present the experimental concept and commissioning of the LRC apparatus, together with the results of the first LRC measurement performed with singly charged lutetium ions (Lu^+), the lighter chemical homologues of lawrencium ions (Lr^+). In particular, hyperfine-structure constants and Einstein A coefficients derived from the measured LRC spectra are reported.

[Poster Session]

Chip-Scale Polarization Detector for Compact SERF Magnetometers

김효기(전남대학교)

Abstract: Optically pumped magnetometers (OPMs) are promising quantum sensors for neuroscience, geophysical exploration, and non-destructive testing, offering high sensitivity, room-temperature operation, and simple architecture. Their performance relies on detecting changes in the polarization of a probe beam, caused by Faraday rotation as it interacts with spin-polarized alkali atoms. However, conventional detection setups, which use polarizing beam splitters and balanced photodetectors, are still too large, making it hard to miniaturize the system further.

Here, we present a chip-scale packaged in-line polarization-resolved detector (CSP-iPRD) integrating a wire grid polarizer (WGP) and a bi-cell photodiode into a compact form factor. With overall dimensions of only 3.5 × 3.5 × 1.8 mm^3, the assembled detector is dramatically smaller than conventional bulk-optic detection setups. Incorporated into a spin-exchange relaxation-free (SERF) OPM with 87Rb, the system achieves a magnetic sensitivity of 33.5 fT/√Hz at 10 Hz, comparable to the 16.1 fT/√Hz at 10 Hz obtained with a conventional detection setup. These results show that our detector can be made even smaller, offering a promising platform for compact, portable OPMs in the future.

[Poster Session]

Three-Body Loss in a ^{23}Na-^{6}Li-^{6}Li Bose-Fermi-Fermi mixture

조현성(서울대학교)

Abstract: Ultracold Fermi gases provide a versatile platform for studying impurity physics because their interactions can be tuned over a wide range using Feshbach resonances. Using atom-loss measurements, we investigate the stability of a two-component ^{6}Li Fermi gas across the BEC–BCS crossover, with bosonic $^{2}3Na$ impurities immersed in the gas. The ^{23}Na–^{6}Li–^{6}Li mixture exhibits enhanced atom loss on the high-field side of the broad ^{6}Li Feshbach resonance, showing behavior distinct from that of previously studied atomic mixtures. In the unitary Fermi gas (UFG) regime, the three-body loss coefficient appears to scale as $1/T^2$, whereas this temperature dependence is not observed in a two-component ^{6}Li gas without ^{23}Na impurities. These results reveal modified three-body loss dynamics and suggest that ^{23}Na impurities may serve as a probe of pair correlations in the ^{6}Li gas.

[Poster Session]

174Yb Tweezer Machine

임태균(KAIST)

Abstract: We present the design of a 174Yb neutral-atom tweezer apparatus. The system combines a 300mm long permanent magnet Zeeman slower, a 2D MOT, a core-shell MOT, and a moving optical lattice to load atoms into a science cell. A protective window heated to 400 Celsius is positioned in front of the Zeeman slower beam viewport to reduce Ytterbium deposition on the viewport. The vacuum system is designed with consideration of chamber geometry, material selection, pumping source, and outgassing to support ultrahigh vacuum operation. Based on a previously demonstrated vacuum architecture, the design targets a pressure of approximately 2e-12mbar, potentially supporting atomic lifetimes exceeding 2,000s.