Live Session
Room Live-2 - Session LI-WeA2

Wednesday Afternoon Live Session II: Stop Worrying and Learn to Enable Quantum Science

Moderators: Charles R. Eddy, Jr., Office of Naval Research Global - London, UK, Rachael Myers-Ward, U.S. Naval Research Laboratory

12:50pm **LI-WeA2-1 Welcome and Opening Remarks***, **Chip Eddy**,* Office of Naval Research Global - London, UK

Welcome to the AVS 67 Virtual Symposium! We hope you will enjoy the event!

12:55pm **LI-WeA2-2 X-Rays Approaching Neutrons: RIXS with Ultrahigh Resolution and Applied Magnetic Field to Study a Magon-spinon dichotomy in β-Li_2IrO_3***, **Alex Frano**,* University of California, San Diego **INVITED**

The family of tri-coordinated iridates have been identified as potential candidates supporting a Kitaev quantum spin liquid, in which spins fractionalize into emergent Majorana fermions and magnetic flux excitations. These quasiparticles acquire long-range topological entanglement and are ideal for fault-tolerant quantum computers. While the presence of additional interactions usually leads to conventional ordering, a dominant Kitaev exchange leads to QSL behavior after the magnetic order is suppressed by temperature or magnetic field, with signatures appearing in thermodynamic measurements and dynamical probes.

β-Li_2IrO_3 is an intriguing example of the complex interplay between Kitaev coupling and magnetic field. At low temperatures, an applied field rapidly suppresses the incommensurate spiral order and drives the system into a uniform field-induced zig-zag state, which are strongly intertwined due to Kitaev interactions. Moreover, a magnetic anomaly has been observed at 100K, with an onset in magnetization and a crossover in the heat capacity without causing true magnetic order. Although these results have been suggested to emerge from thermal fractionalization of the spins, very little is known about the low-energy magnetic excitations.

In this work, we present a comprehensive picture of the dynamical response of β-Li_2IrO_3 in an applied magnetic field. The spin excitations were measured using a high-resolution RIXS spectrometer, which identified dispersing spin waves reaching a maximum of 16meV, in perfect agreement with semiclassical calculations of the dynamical spin structural factor for the intertwined states. The low-energy magnon is superimposed by a broad continuum of excitations centered around 35meV, which is unaffected by the low-temperature ordered states but sensitive to the high temperature anomaly. This continuum is consistent with the onset of nearest neighbor correlations emerging from a dominant Kitaev energy scale, and alludes to the long coherence time of the fractional excitations in the proximate QSL phase.

1:15pm **LI-WeA2-6 X-Ray Spectroscopies With Increased Resolution: Principles and Perspectives***, **Lucia Amidani**,* ESRF, France **INVITED**

In was only in the early 90s that the use of hard X-ray emission spectrometers to collect X-ray Absorption spectra was first suggested [1]. X-ray emission spectrometers based on Bragg's law achieve resolutions below 2 eV, a huge improvement compared to solid-state detectors whose resolution is only 150 – 200 eV. With this technical improvement, the characteristic fluorescence of the excited atoms is collected with a resolution below the core-hole lifetime broadening, resulting in better-resolved XAS spectra [2]. Since then, the use of X-ray Spectroscopies with improved resolution exploded and dedicated synchrotron beamlines multiplied. Nowadays, these techniques are largely exploited in many diverse fields of science.

Lanthanides and actinides are among the elements that profit the most of the improved resolution because of their large core-hole lifetime broadenings. Indeed, the demonstration of principle was done on Dy L_3 edge XANES [1]. For actinides, the resolution at L_3 edge is largely improved, but the biggest boost was given to $M_{4,5}$ edges, whose conventional XANES are almost featureless. These edges probe directly the 5f states. With better-resolved spectra, the oxidation state can be easily determined and the spectral features that were invisible before bring information about the local coordination and the charge exchange with ligands [3,4].

The information encrypted in these spectra is enormous. Improved resolution makes it more readily available by disclosing details and allowing smaller differences to be appreciated. However, the interpretation often represent the bottleneck to the extraction of relevant information. In this respect, theoretical simulations are fundamental. Nowadays, we have several user-friendly codes that interprets the spectra starting from different approaches, focusing on the intra-atomic interactions or favouring the multi-atomic picture of the system studied.

In this talk, I will briefly introduce some of the techniques exploiting the improved resolution and then focus on their application to actinide science. I will present few examples illustrating the high potential of these techniques and the approach we use in our group to interpret the data [5–7].

References:

[1] K. Hämäläinen et al., Phys. Rev. Lett. **67**, 2850 (1991).

[2] P. Glatzel et al., J. Electron Spectrosc. Relat. Phenom. **188**, 17 (2013).

[3] K. O. Kvashnina et al., Phys. Rev. Lett. **111**, 253002 (2013).

[4] K. O. Kvashnina et al., J. Electron Spectrosc. Relat. Phenom. **194**, 27 (2014).

[5] L. Amidani et al., Phys. Chem. Chem. Phys. **21**, 10635 (2019).

[6] K. O. Kvashnina et al., Angew. Chem. Int. Ed. **58**, 17558 (2019).

[7] A. S. Kuzenkova et al., Carbon 291 (2020).

1:35pm **LI-WeA2-10 Exploring Materials, Surface Treatments and Junctions for Superconducting Quantum Circuits***, **Martin Sandberg**,* IBM **INVITED**

Multifunctional material stacks compatible with high coherence superconducting quantum circuits could lead to more efficient circuit implementations. One material with a multitude of applications in optics and electronics is silicon-germanium (SiGe). Here we show that a Si/SiGe heterostructure can be incorporated in superconducting quantum circuits without any coherence degradation [1]. This opens pathways for on-chip optical to microwave transduction among other highly attractive applications.

In addition to the SiGe work we will show the effect of various in-situ surface treatments on flux tunable superconducting qubits in a hermetic package [2], as well as the effect of Two Level Systems (TLSs) in large junction Al/AlOx/Al Merged Element Transmons (MET) [3]. Our studies suggest that surface treatments can reduce the 1/f flux noise without necessarily reducing energy relaxation. For the MET qubits we find that large Al/AlOx/Al junctions contains very strongly coupled TLSs and exhibit large fluctuations in energy relaxation times. Despite the large junction area we still observe energy relaxation times higher than 200 microseconds over several hours of measurements for the best performing devices.

Reference:

[1] Investigating microwave loss of SiGe using superconducting transmon qubits

Martin Sandberg, Vivekananda P. Adiga, Markus Brink, Cihan Kurter, Conal Murray, Marinus Hopstaken, John Bruley, Jason Orcutt, Hanhee Paik

Appl. Phys. Lett. **118**, 124001 (2021)

[2] Effects of surface treatments on flux tunable transmon qubits

M. Mergenthaler,C. Müller, M. Ganzhorn, S. Paredes, P. Müller, G. Salis, V. Adiga,M. Brink,2 M. Sandberg, J. Hertzberg, S. Filipp, and A. Fuhrer

arXiv:2103.07970

[3] Merged-Element Transmons: Design and Qubit Performance

H. J. Mamin, E. Huang, S. Carnevale, C. T. Rettner, N. Arellano, M. H. Sherwood, C. Kurter, B. Trimm, M. Sandberg, R. M. Shelby, M. A. Mueed, B. A. Madon, A. Pushp, M. Steffen, D. Rugar.

arXiv:2103.09163

2:05pm **LI-WeA2-16 Engineering Superconducting Quantum Systems***, J. Yoder, **Donna Ruth Yost**,* MIT Lincoln Laboratory **INVITED**

Development of qubits – the fundamental logic element of a quantum processor – is transitioning from a scientific discovery phase to an engineering pursuit. In order to reach the scale needed for a broad range of quantum computing applications, key challenges now lie in engineering these quantum systems at every level from individual qubits to highly complex circuits. In this talk I will describe our quantum engineering of superconducting qubit systems, including our approach to predictive control of individual qubits and our three-tier stack platform for extending high-coherence circuits to increasing scale and complexity.

This research was funded in part by the Office of the Director of National Intelligence (ODNI), Intelligence Advanced Research Projects Activity (IARPA) and the Defense Advanced Research Projects Agency (DARPA) under Air Force Contract No. FA8702-15-D-0001. The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of the ODNI, IARPA, DARPA, or the U.S. Government.

2:25pm **LI-WeA2-20 Micro-Scale Fusion and Neutron Generation from Nanowire Arrays Irradiated With Ultrashort Laser Pulses of Relativistic Intensity***, **Jorge Rocca**, A. Curtis, C. Calvi,* Colorado State University*; J. Tinsley,* Mission Support and Test Services*; S. Wang, R. Hollinger, H. Song,* Colorado State University*; M. Capeluto,* Colorado State University, USAUniversidad de Buenos Aires, Buenos Aires, Argentina*; Y. Wang, V. Shlyaptsev,* Colorado State University*; V. Kaymak, A. Pukhov,* Heinrich-Heine-Universität Düsseldorf, Germany **INVITED**

The irradiation of arrays of aligned deuterated polyethylene nanowires (CD2) with ultra-high contrast femtosecond laser pulses of relativistic intensity was recently shown to accelerate deuterons to multiMeV energy and to efficiently produce flashes of quasi-monoenergetic fusion neutrons [1]. The trapping of femtosecond laser pulses of relativistic intensity deep within ordered nanowire arrays can volumetrically heat dense matter into a new ultra-hot plasma regime [2,3]. Electron densities more than 100 times greater than the critical density with multi-keV temperatures are achieved using ultrashort laser pulses of only a few Joule energy focused to relativistic intensities. The number of fusion neutron produced exceeds by > 500 times that produced irradiating flat solid CD2 targets with the same laser pulses. Those experiments were conducted at irradiation intensities below 1 x 10 20 W cm-2. We also present recent results of deuteron acceleration from experiments conducted at irradiation intensities of ~ 2 x 10 21 W cm-2. The deuterons are measured to be accelerated to energies of several tens of MeVs and to be emitted in a cone of approximately 10 degrees half-angle. 3-D fully relativistic particle in cell computations are used to elucidate the mechanisms of ions acceleration in the nanowire arrays, which extend beyond target normal sheet acceleration. The fundamental physics of relativistic laser pulse interactions with nanostructures and their promising applications will be reviewed.

Work supported by the Air Force Office of Scientific Research under award number FA9550-17-1-0278 the U.S. Department of Energy, Fusion Science program of the Office of Science using laser facilities of LaserNet US, and MSTS. 1. A. Curtis, et al. , "Micro-scale fusion in dense relativistic nanowire array plasmas". Nature Communications. 9, 1077, (2018). 2. M.A. Purvis, et al., “Relativistic plasma nano-photonics for ultra-high energy density physics,” Nature Photonics 7,796, (2013). 3. C. Bargsten, et al. "Energy Penetration into Arrays of Aligned Nanowires Irradiated with Relativistic Intensities: Scaling to Terabar Pressures," Science Advances, 3, e1601558, (2017)

2:45pm **LI-WeA2-24 The NIST Quantum Logic Clock and its Vacuum Performance***, **David Leibrandt**,* NIST-Boulder **INVITED**

Optical atomic clocks have achieved fractional measurement precision and accuracy at the 10^{-18} level, making them the lowest uncertainty measurement devices of any kind. In this talk, I will describe an optical clock based on quantum-logic spectroscopy of a single Al^+ ion co-trapped with a single Mg^+ ion in an ultra-high vacuum (UHV) environment. Collisions of the ions with background gas molecules degrade the stability of the clock, and cause a systematic frequency shift which must be characterized. By measuring the rate of collisions that cause reordering of the Al^+/Mg^+ ion pair and performing collision kinematics modeling, we determine the background-gas pressure in situ to be 38(19) nPa, where the uncertainty is dominated by the inaccuracy of the semiclassical differential cross sections we use in the model. By incorporating fully quantum scattering calculations, it may be possible to use this pressure measurement technique as the basis of a primary pressure standard for UHV and XHV.

3:05pm **LI-WeA2-28 Closing Remarks and Thank You's***, **Rachael Myers-Ward**,* Naval Research Laboratory

Thank you for attending today's session! Remember to check out the AVS 67 On Demand Sessions which are available in the mobile app and online scheduler until 11/30/21 and then in the AVS Technical Library for all Platinum Members. We will see you at AVS 68 in Pittsburgh, PA, November 6-11, 2022!

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