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10 June 2021, 10:00–11:00h

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(Meeting-ID: 912 0213 7161, Password: 845021)

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Echoes Made Simple:
from molecular alignment to the spectroscopy of gravitational quantum states

Echoes are common in many areas of physics, including NMR, plasma physics, nonlinear optics, cavity quantum electrodynamics, cold atoms physics, and dynamics of proton storage rings. Recently, we found (probably) the simplest classical system featuring the echo phenomenon — a collection of randomly oriented free rotors with dispersed rotational velocities. Following the excitation by a pair of time-delayed impulsive kicks, the mean orientation or alignment of the ensemble exhibits multiple echoes and fractional echoes. These echoes result from kick-induced filamentation of the rotational phase space, and I will present a simple toy model explaining this phenomenon at the high school level.

Then, I will present the first experimental demonstration of the predicted alignment echoes (full and fractional) in a thermal gas of CO_2 molecules excited by a pair of femtosecond laser pulses [1,2]. Later on, we used the technique of coincidence Coulomb explosion imaging for direct spatiotemporal analysis of various molecular alignment echoes (full, fractional, rotated, and imaginary) [3]. The described mechanism of the echo formation is rather general and has implications in other fields of physics. The SLAC demonstration of the efficient generation of high harmonics (up to the 75th) from tailored electron beams in free-electron lasers [4] is based on a mechanism similar to fractional echoes of high order observed in our molecular experiments. Alignment echoes provided an efficient tool for studies on collisional relaxation in dense molecular gases [5]. Recently, the generalization of the phase space filamentation mechanism to vibrational motion allowed us to observe quantum echoes in single Ar_2 ions [6]. If time permits, we will discuss how the search for echoes in single quantum systems led us to suggest a new kind of spectroscopy of the Gravitational Quantum States (GQS) of ultra-cold neutrons, atoms, and anti-atoms bouncing in the Earth's gravitational field [7].

Host: Jochen Küpper/ CFEL Molecular and Ultrafast Science Seminar

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SEMINAR

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3. K. Lin, P. Lu, J. Ma, X. Gong, Q. Song, Q. Ji, W. Zhang, H. Zeng, J. Wu, G. Karras, G. Siour, J.-M. Hartmann, O. Faucher, E. Gershnabel, Y. Prior, and I. Sh. Averbukh, *Phys. Rev. X* **6**, 041056 (2016).
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6. J. Qiang, I. Tutunnikov, P. Lu, K. Lin, W. Zhang, F. Sun, Y. Silberberg, Y. Prior, I. Sh. Averbukh, and J. Wu, *Nature Physics*, **16**, 328–333 (2020).
7. I. Tutunnikov, K. V. Rajitha , A. Yu. Voronin, V. V. Nesvizhevsky, and I. Sh. Averbukh, *Phys. Rev. Lett.* **126**, 170403 (2021).