

Cavity-enhanced spectroscopy in the deep cryogenic regime – new hydrogen technologies for quantum sensing

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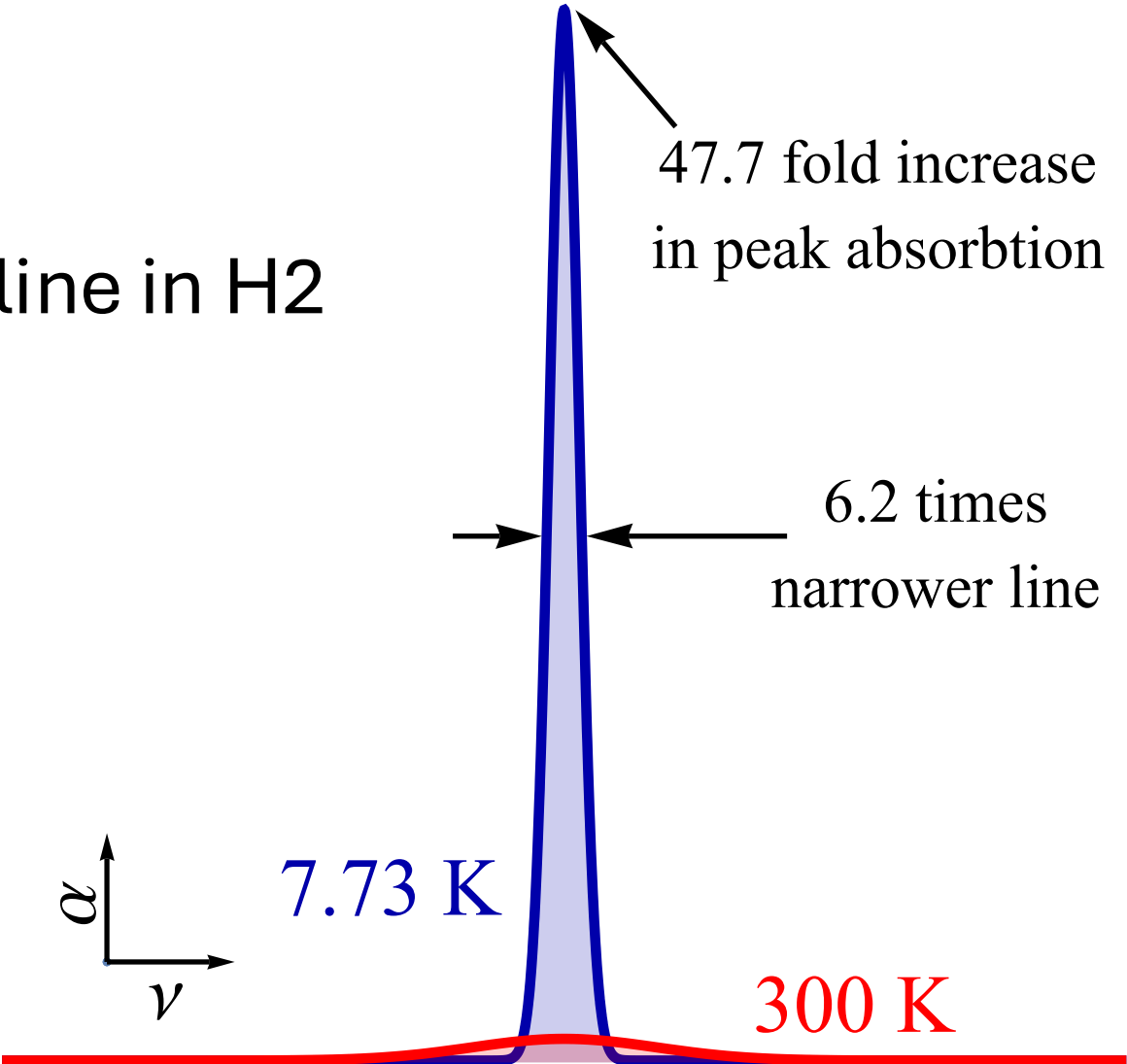
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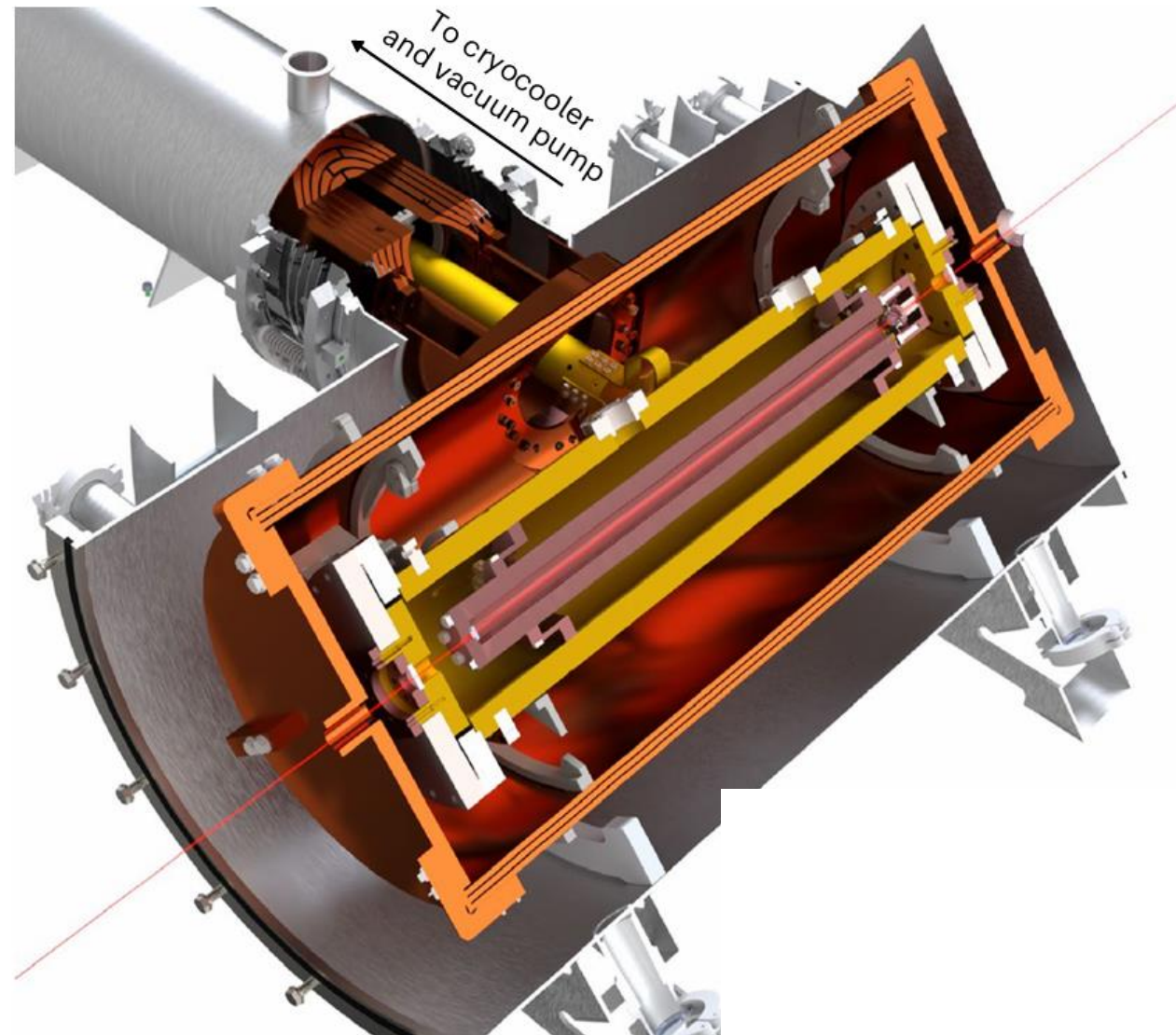
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Line shape simulation at cryogenic and room temperatures

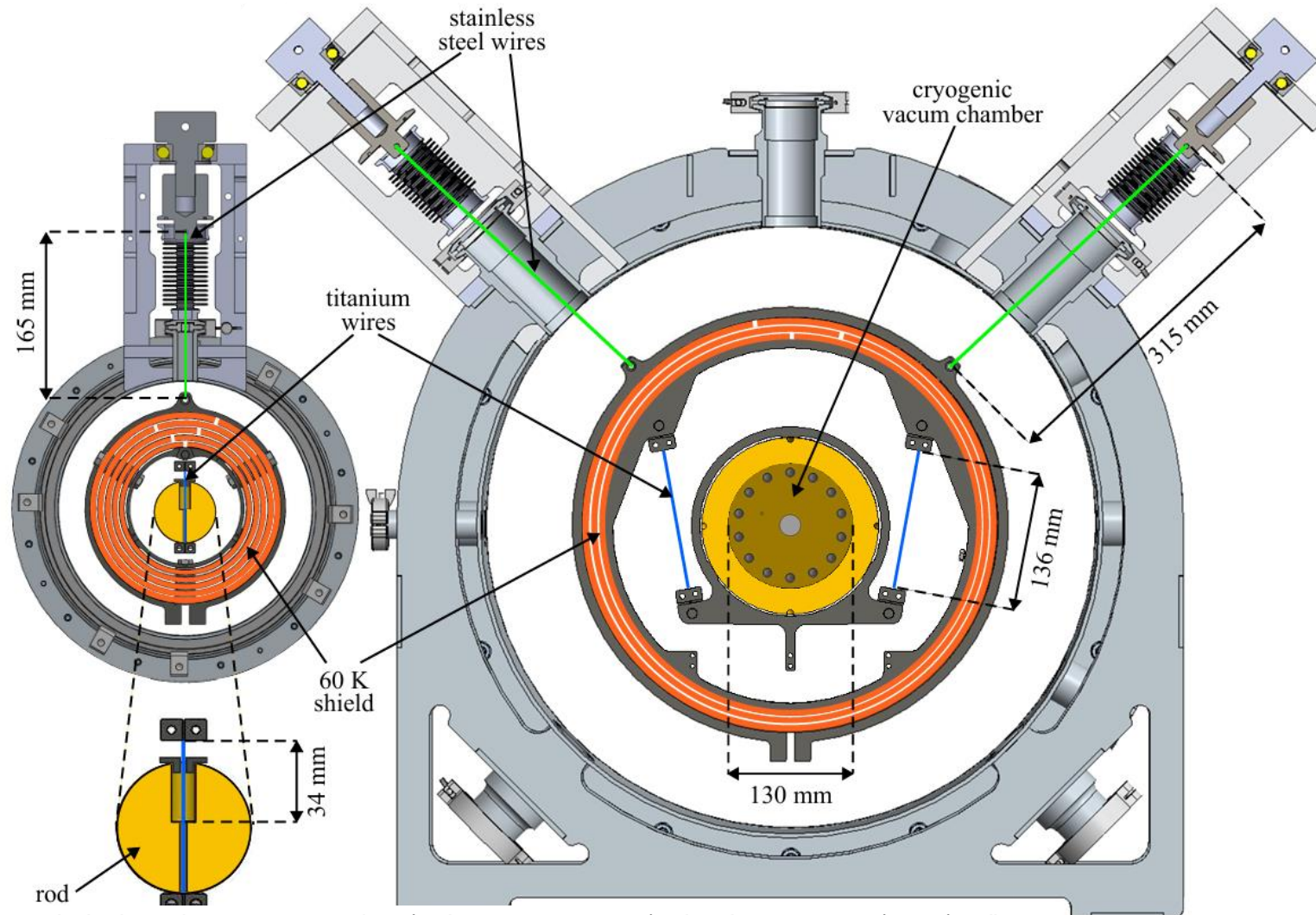
1-0 S(0) line in H₂



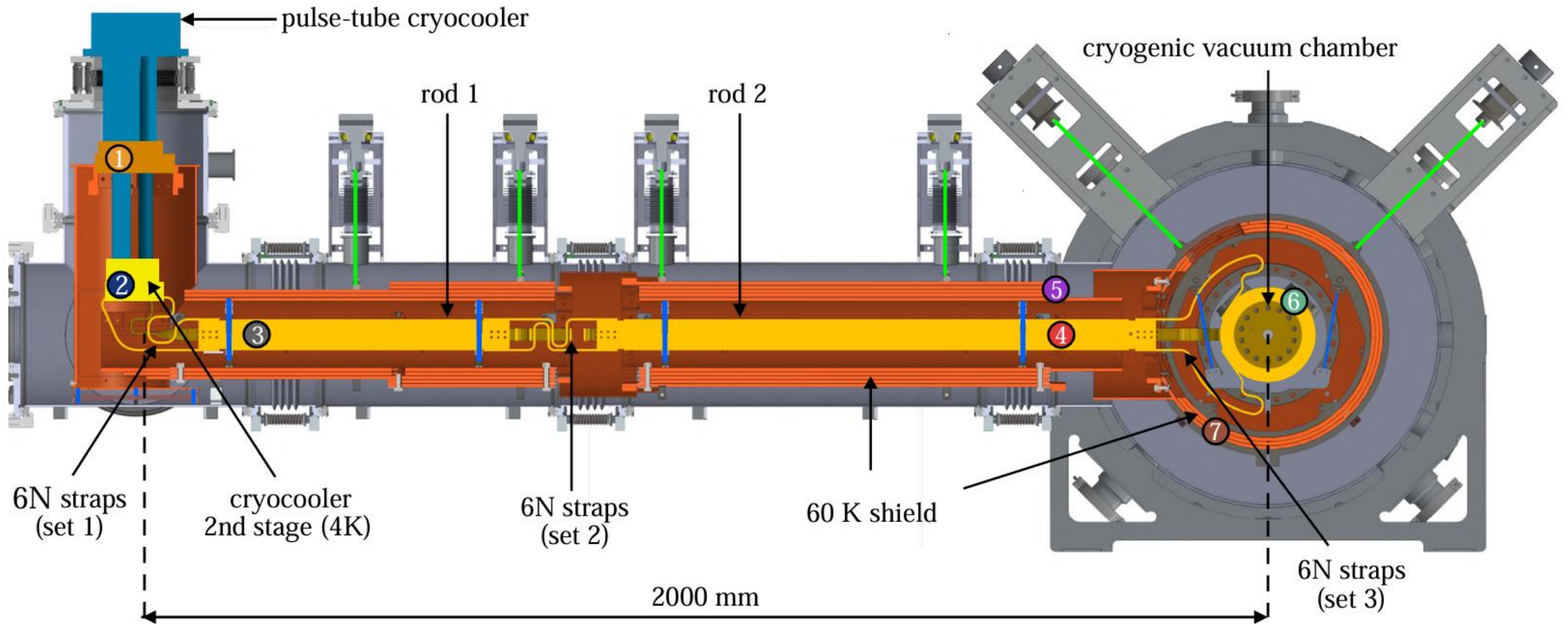
Cryogenic cavity-enhanced spectrometer



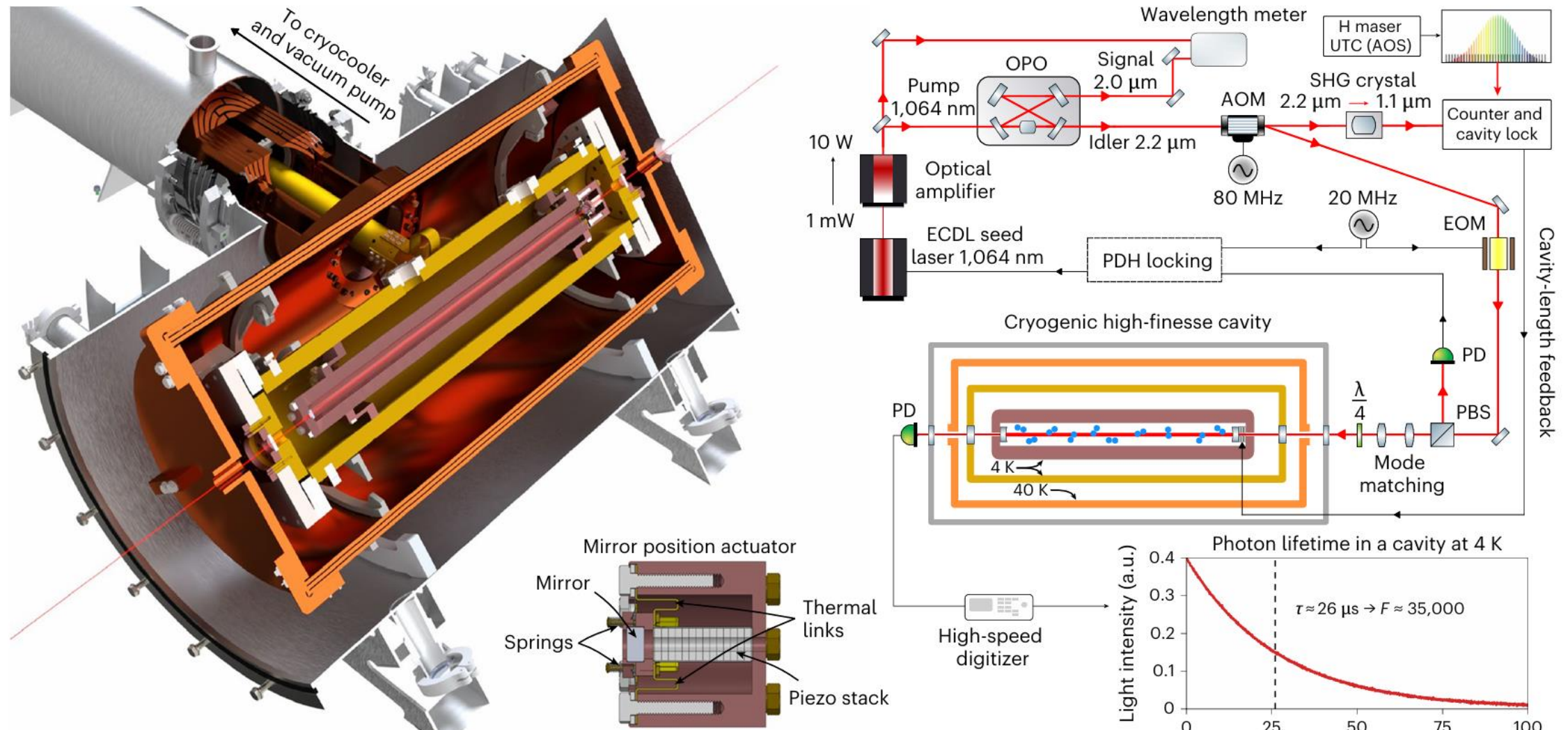
Cryogenic cavity-enhanced spectrometer



Cryogenic cavity-enhanced spectrometer

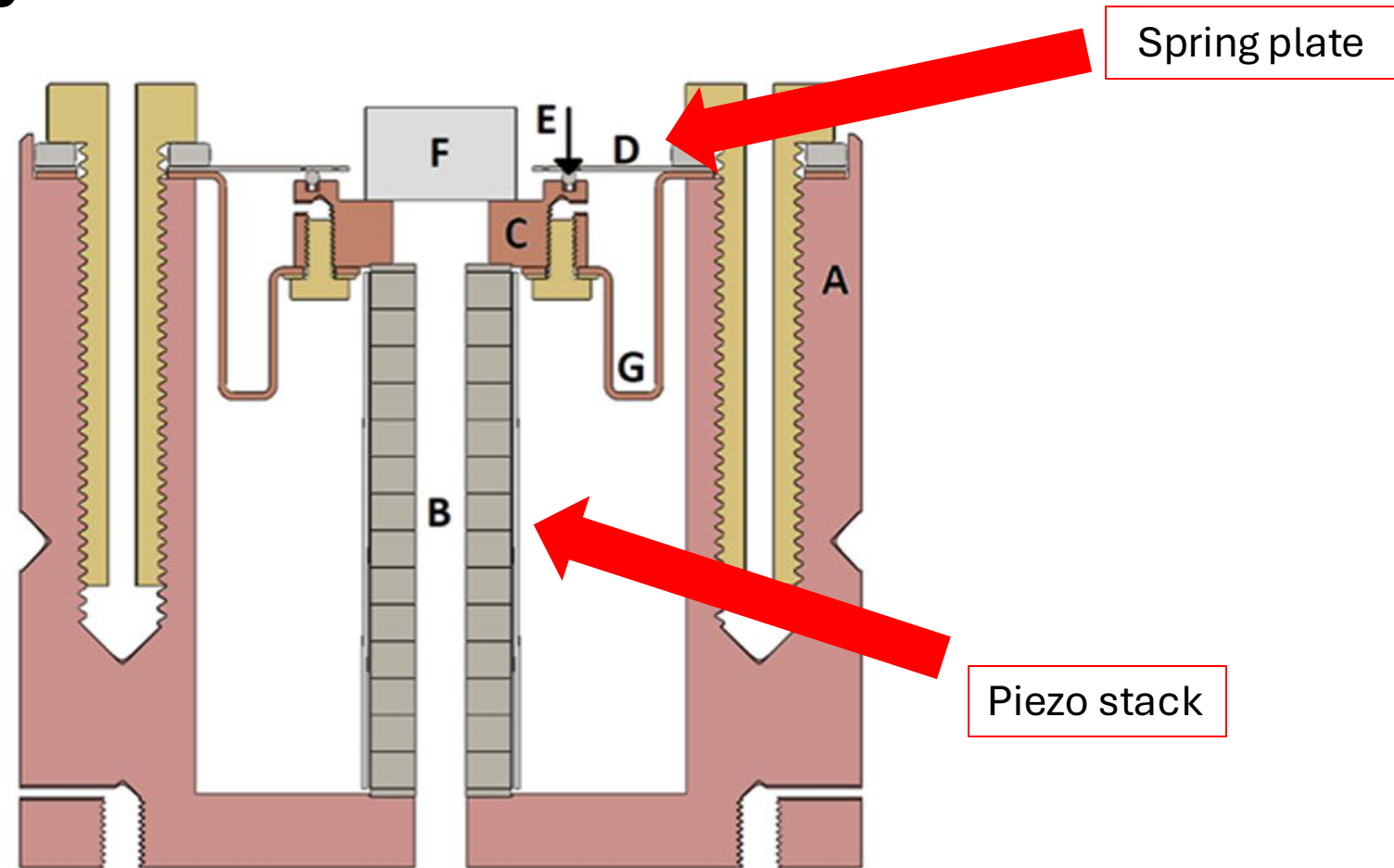


Cryogenic cavity-enhanced spectrometer



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Mirror position actuator for cryogenic spectroscopy

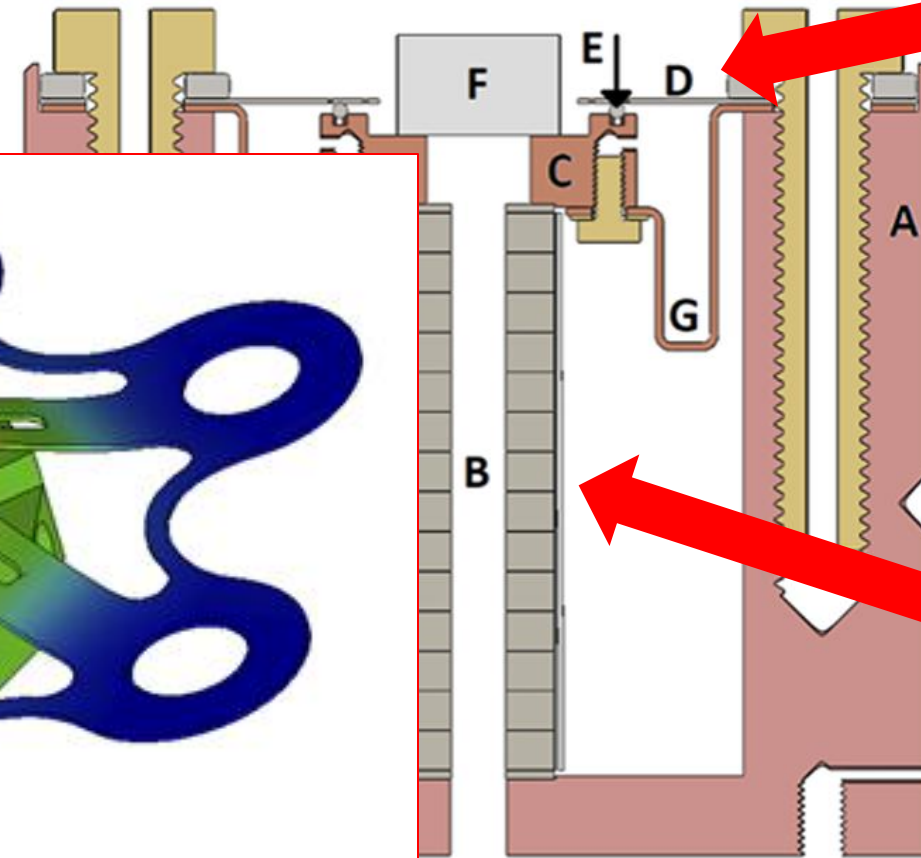
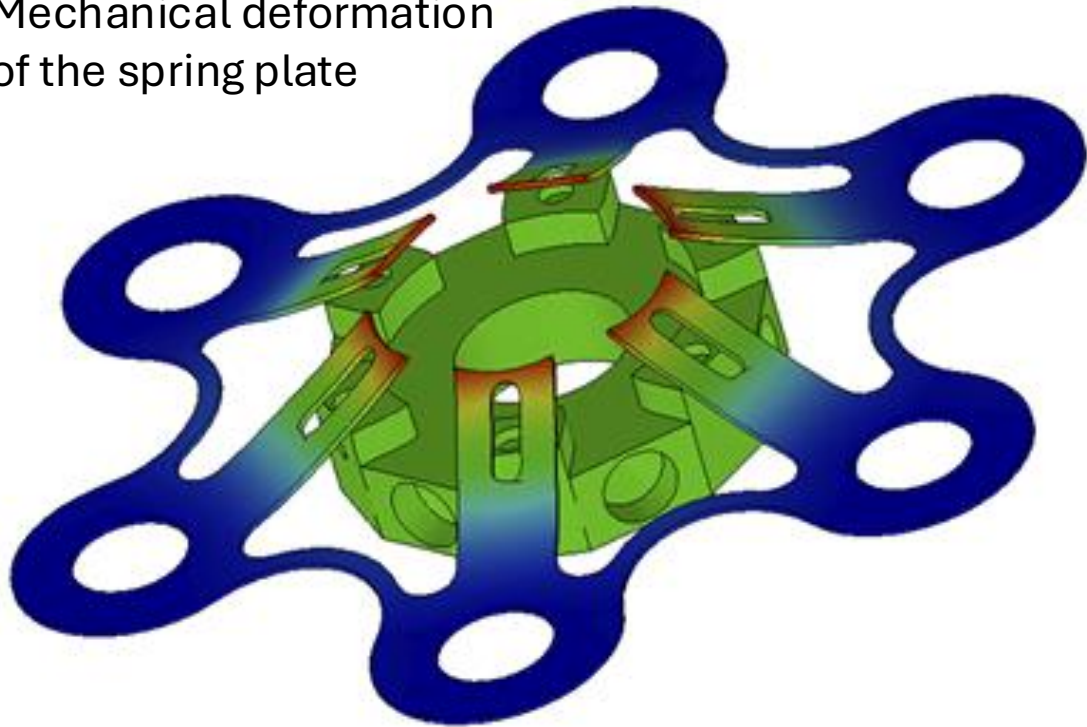


Mirror position actuator for cryogenic spectroscopy

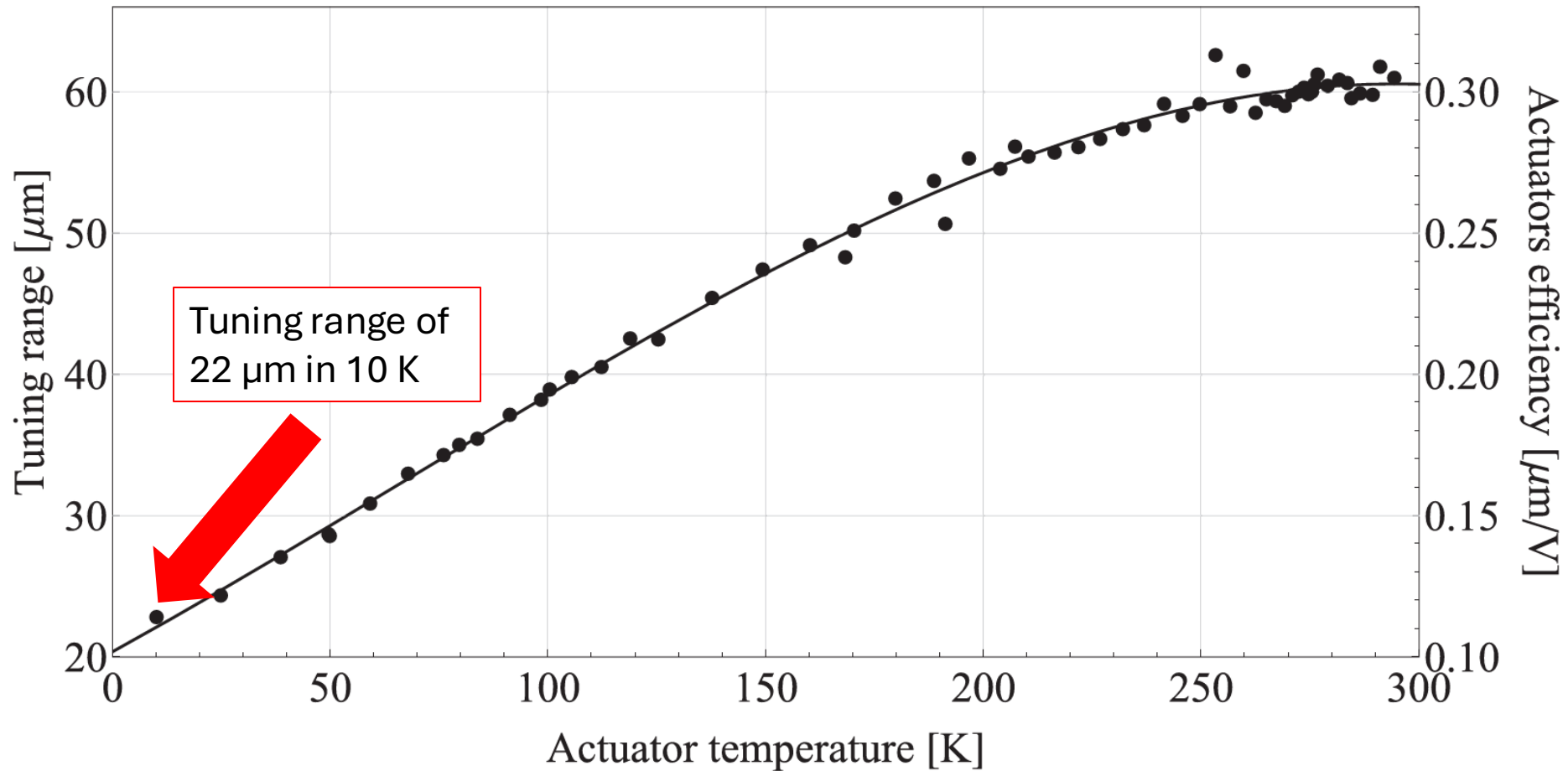
Spring plate

Piezo stack

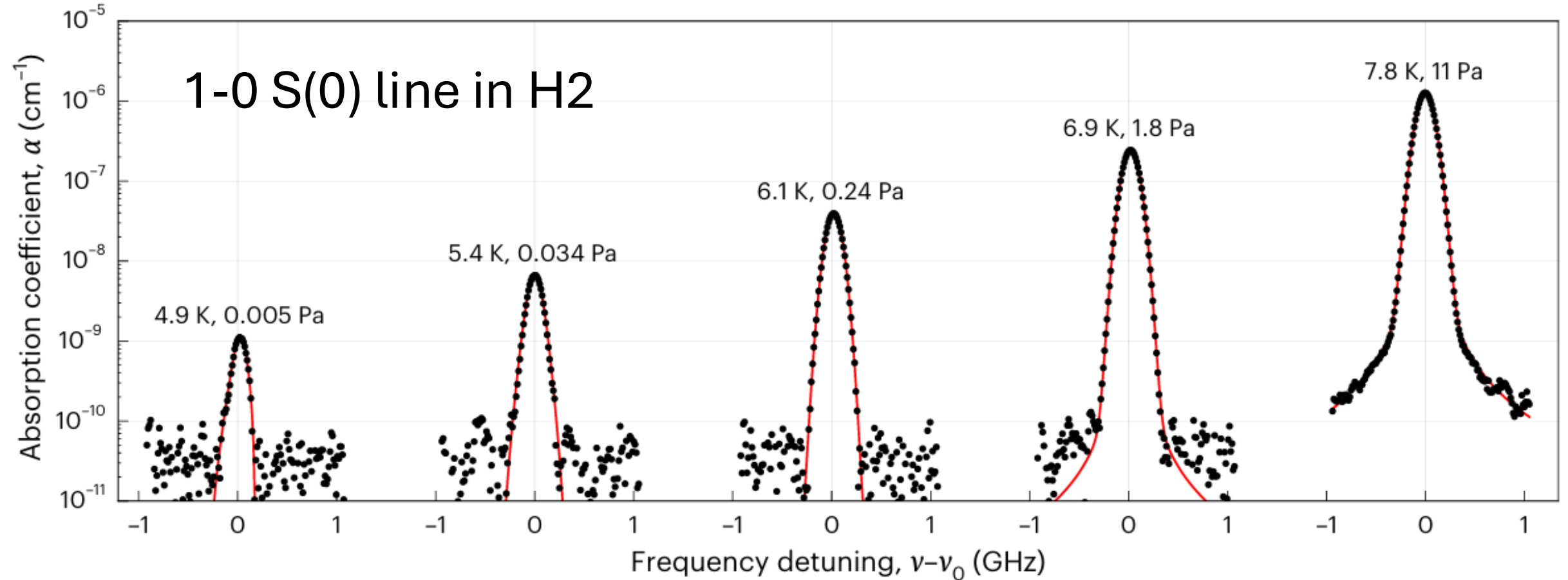
Mechanical deformation of the spring plate



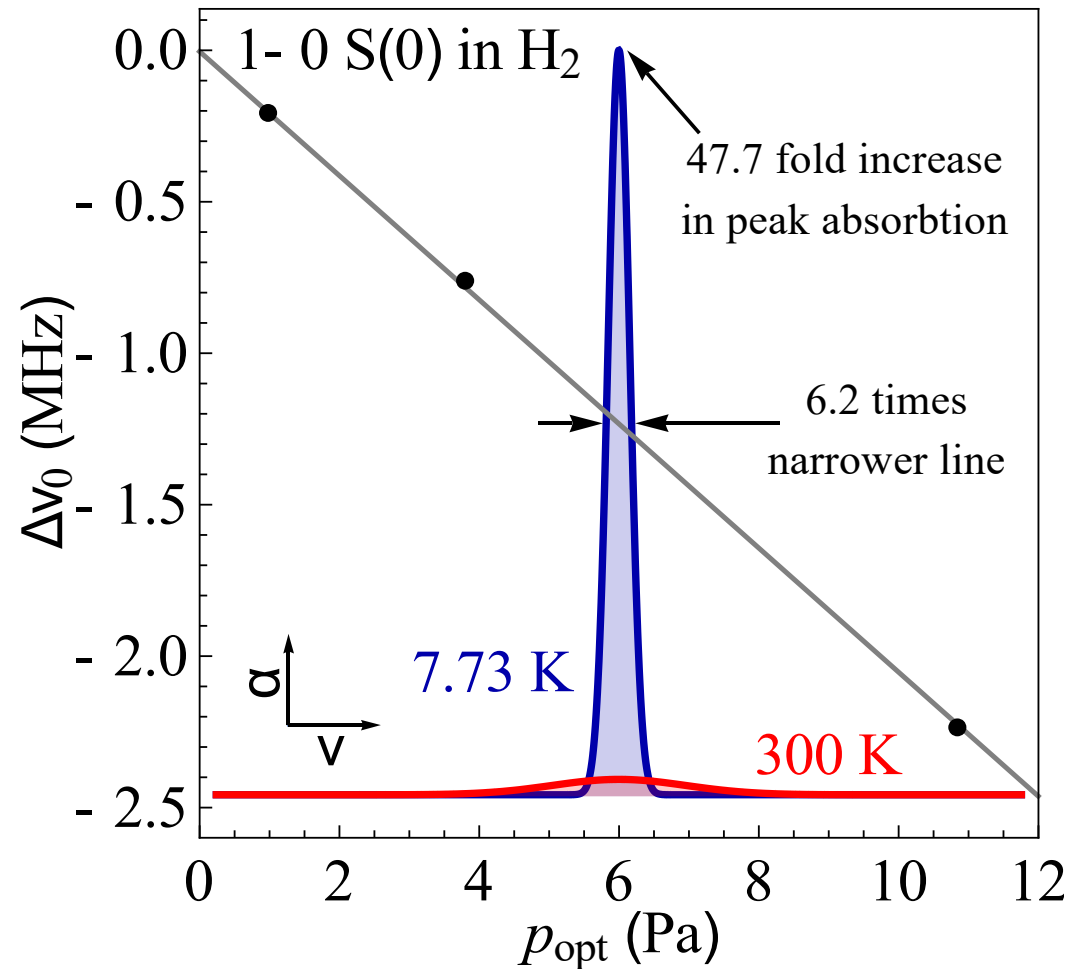
Mirror position actuator for cryogenic spectroscopy



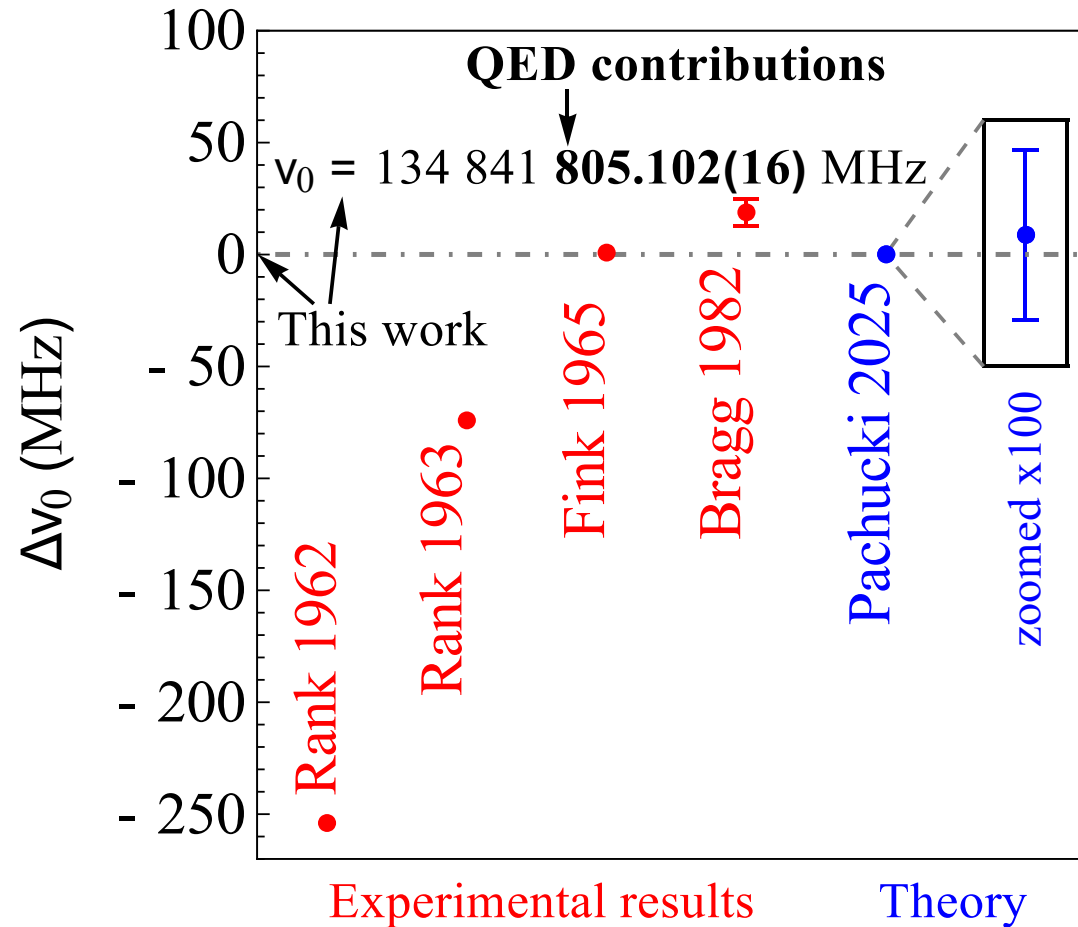
High SNR spectra in cryogenic temperatures



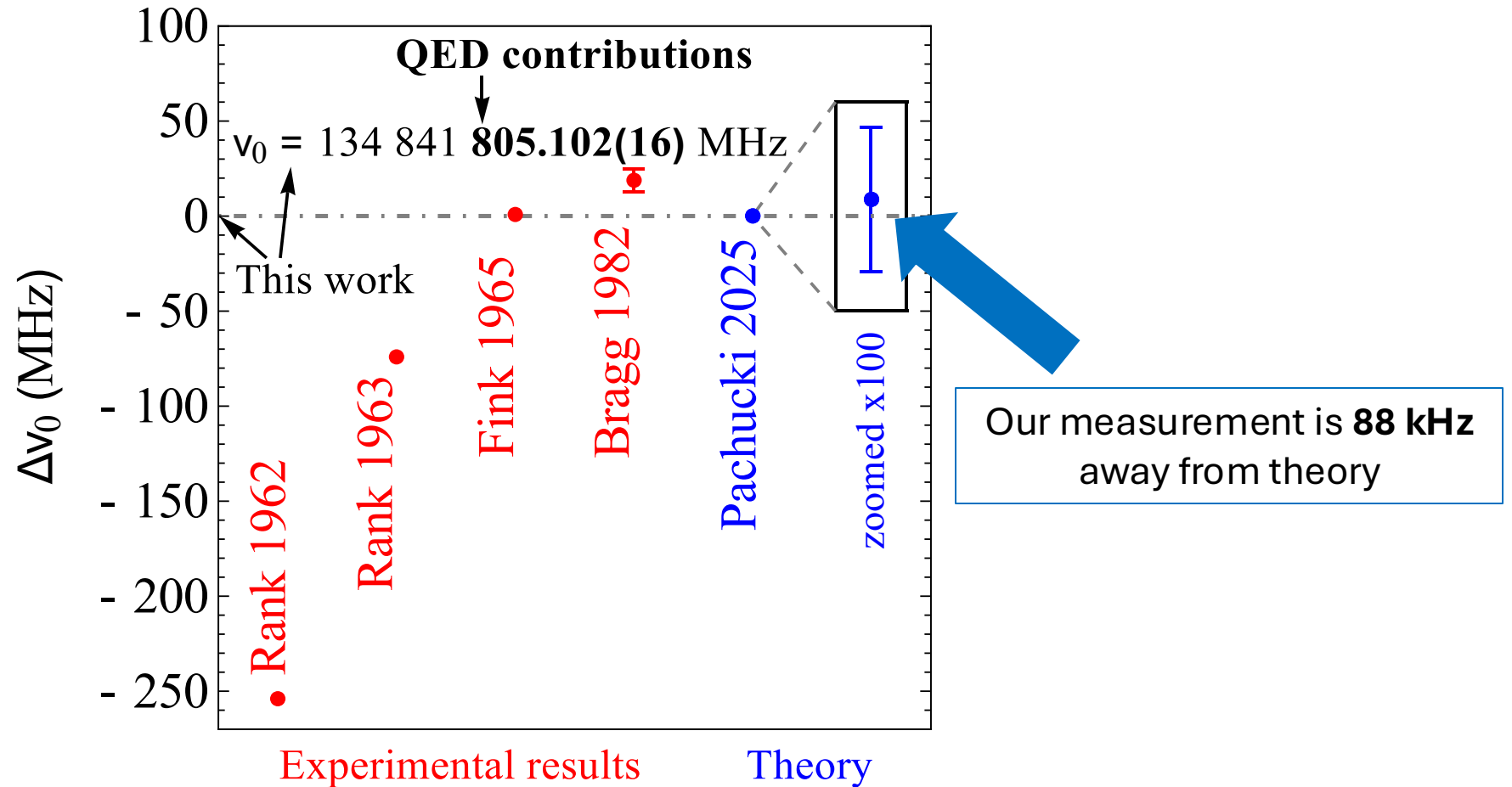
Precise tests of quantum theory for molecules



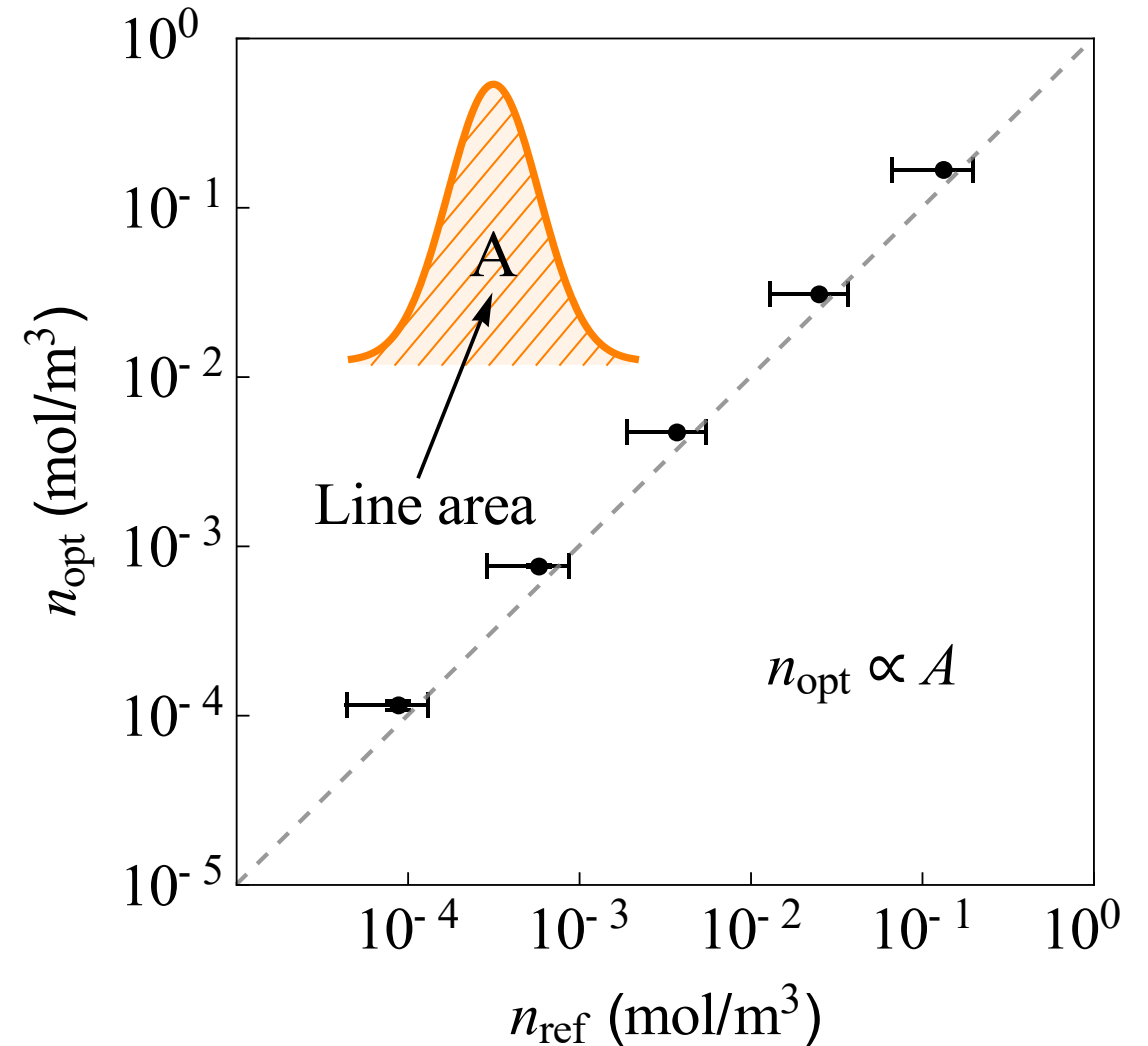
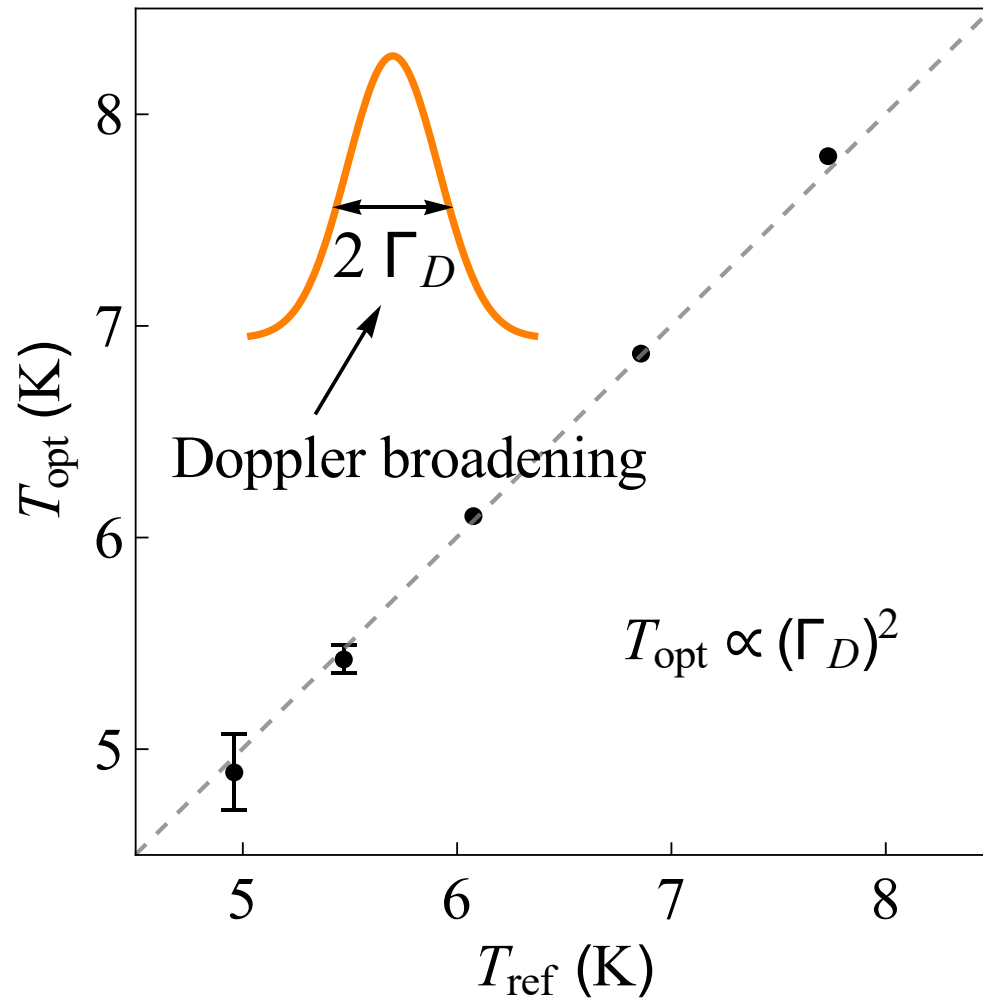
Precise tests of quantum theory for molecules



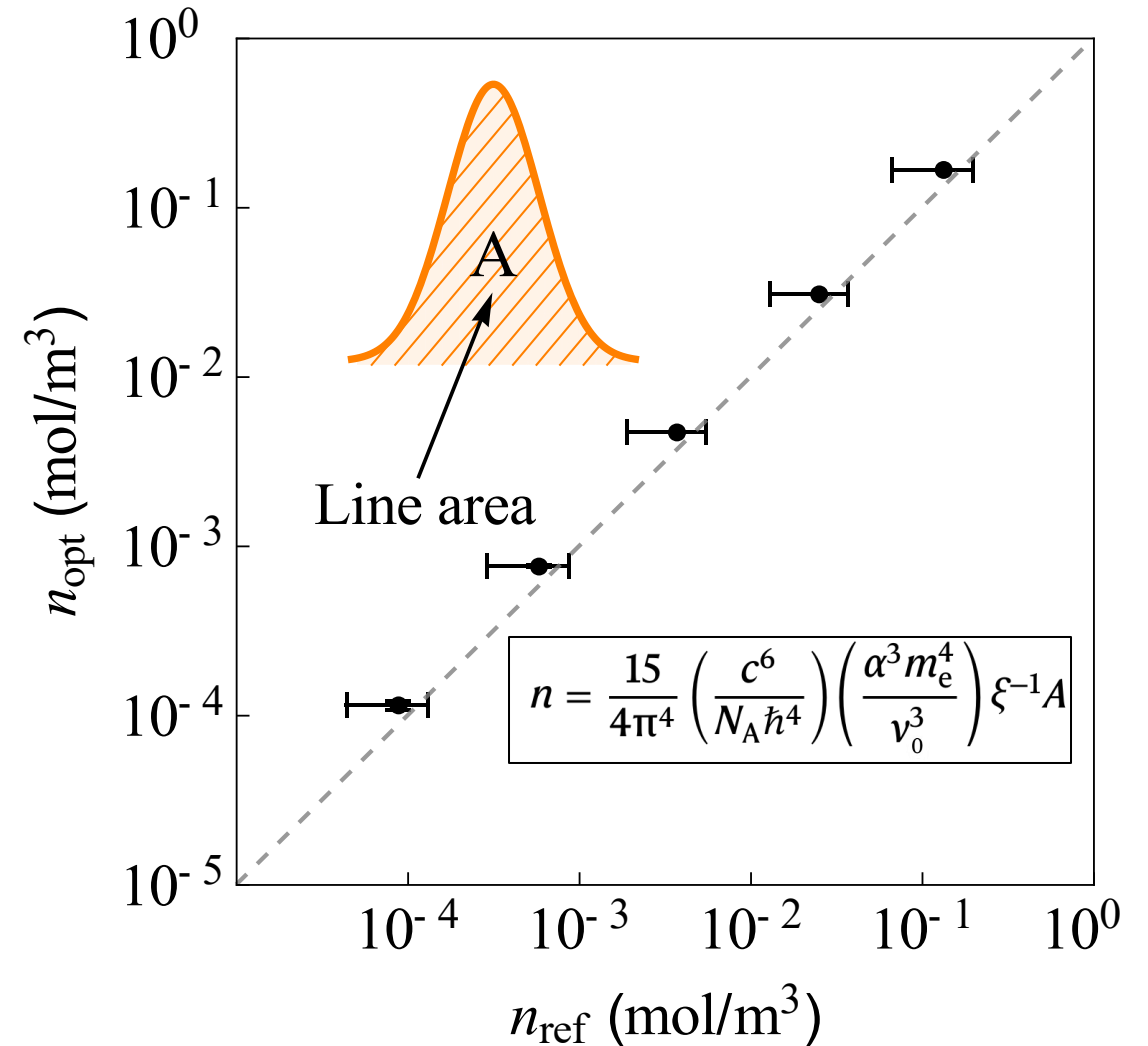
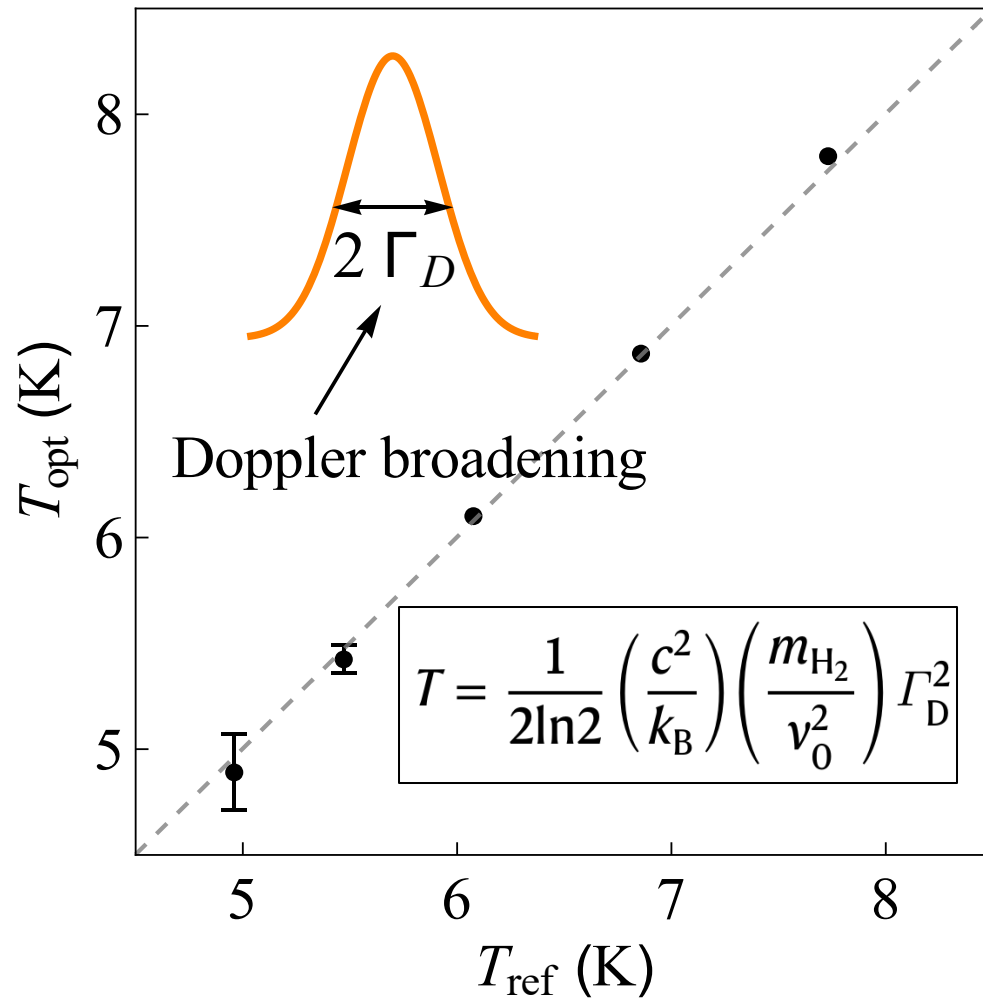
Precise tests of quantum theory for molecules



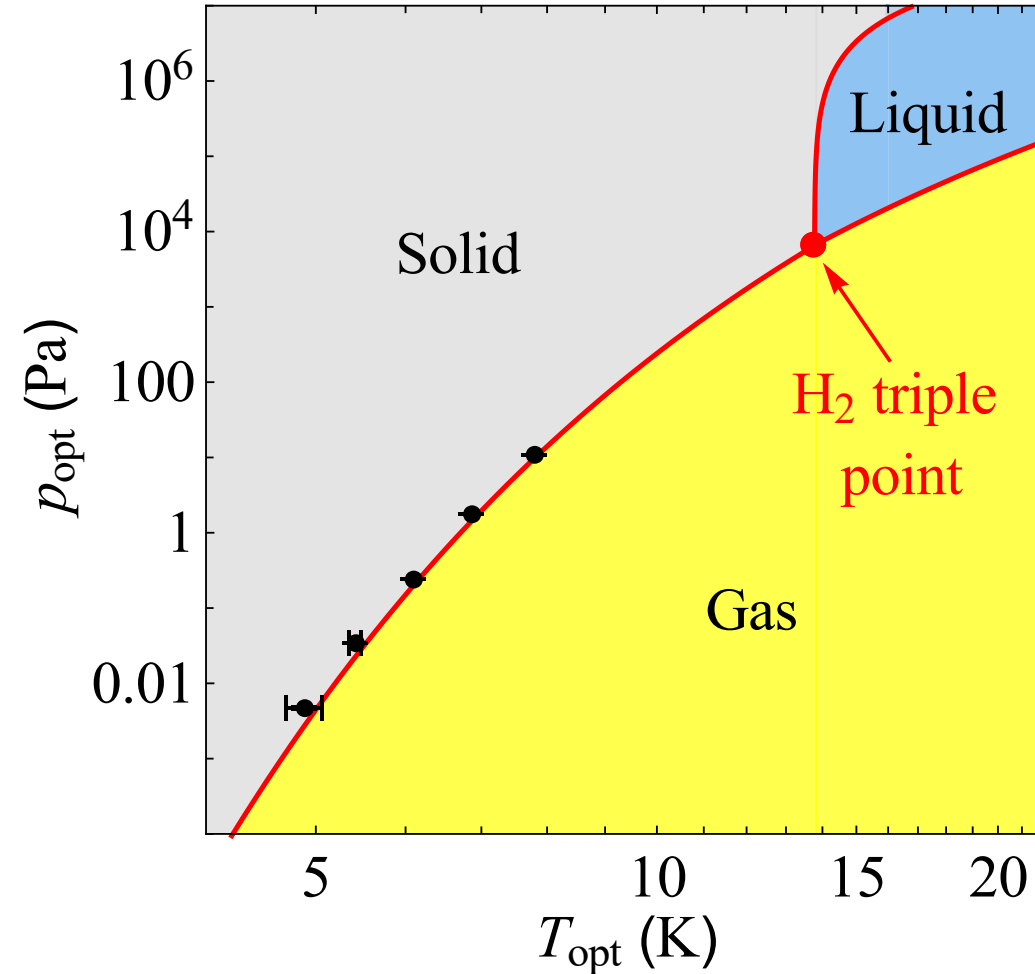
Optical realisation of SI units in cryogenic conditions



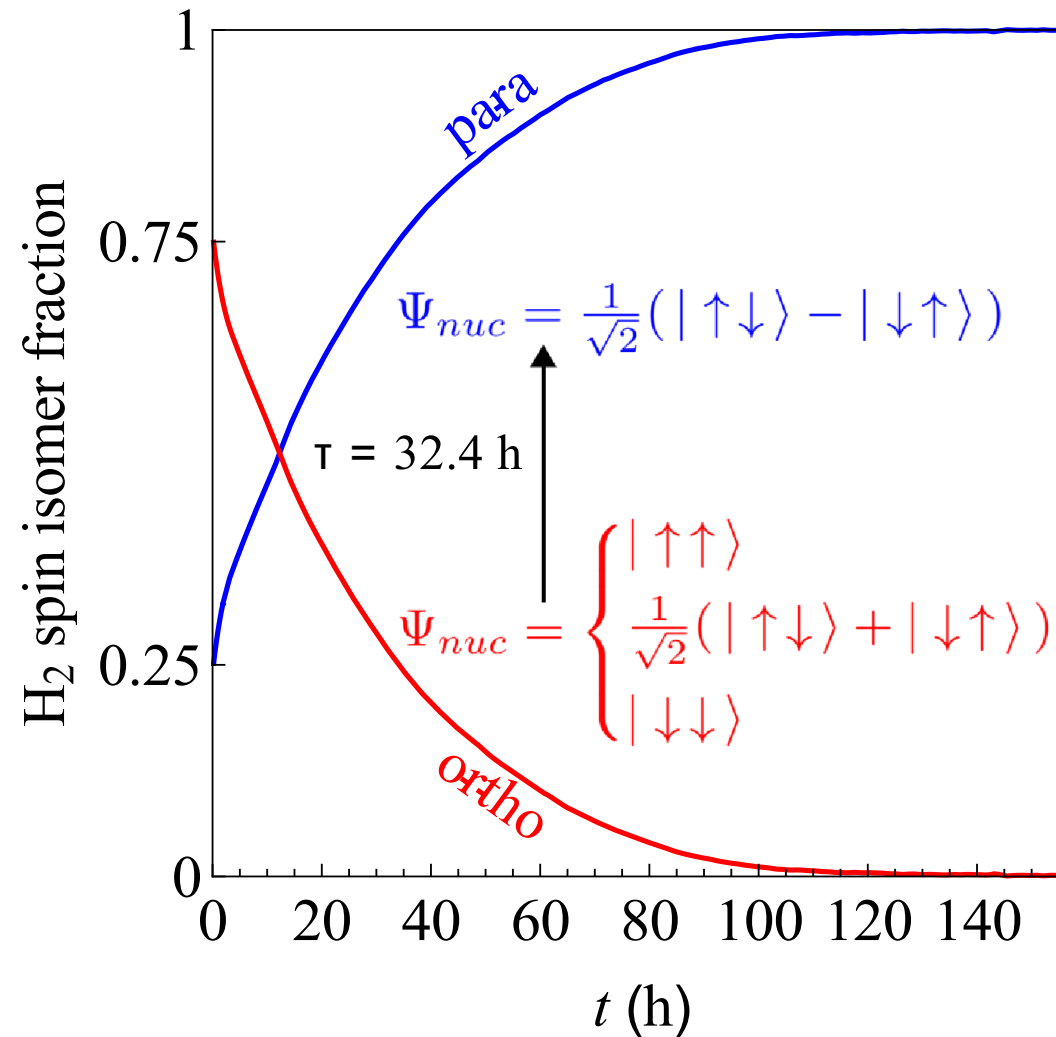
Optical realisation of SI units in cryogenic conditions



Optically determined H₂ phase diagram curve



H2 spin isomer conversion rate



Room for improvement – purely frequency based methods

Cavity mode-width spectroscopy with widely tunable ultra narrow laser

Agata Cygan,^{1,*} Daniel Lisak,¹ Piotr Morzyński,¹ Marcin Bober,¹ Michał Zawada,¹ Eugeniusz Pazderski,² and Roman Ciuryło¹

¹Institute of Physics, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University in Toruń, Poland

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One-dimensional frequency-based spectroscopy

Agata Cygan,^{1,*} Piotr Wcisło,¹ Szymon Wójtewicz,¹ Piotr Masłowski,¹ Joseph T. Hodges,² Roman Ciuryło,¹ and Daniel Lisak¹

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²National Institute of Standards and Technology, Gaithersburg, MD, USA

PHYSICAL REVIEW LETTERS **135**, 103201 (2025)

Leveraging Resonant Frequencies of an Optical Cavity for Spectroscopic Measurement of Gas Temperature and Concentration

Daniel Lisak^{1,*}, Vittorio D'Agostino^{1,2}, Szymon Wójtewicz¹, Agata Cygan¹, Marcin Gibas³, Piotr Wcisło¹, Roman Ciuryło¹, and Katarzyna Bielska¹

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Research Article

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High-accuracy and wide dynamic range frequency-based dispersion spectroscopy in an optical cavity

AGATA CYGAN,^{*} PIOTR WCISŁO, SZYMON WÓJTEWICZ, GRZEGORZ KOWZAN, MIKOŁAJ ZABOROWSKI, DOMINIK CHARCZUN, KATARZYNA BIELSKA, RYSZARD S. TRAWIŃSKI, ROMAN CIURYŁO, PIOTR MASŁOWSKI, AND DANIEL LISAK

Institute of Physics, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University in Toruń, Grudziadzka 5, Torun 87-100, Poland

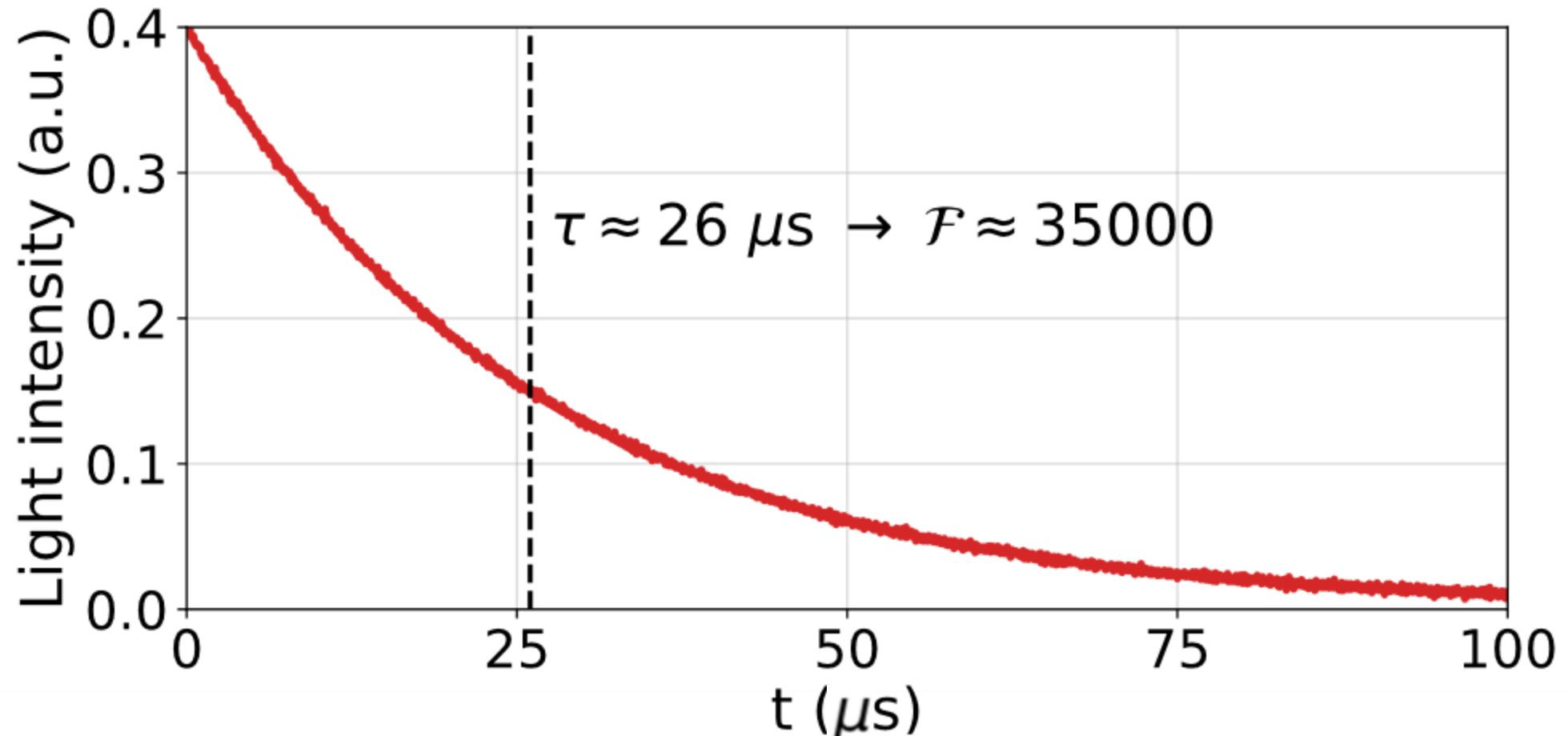
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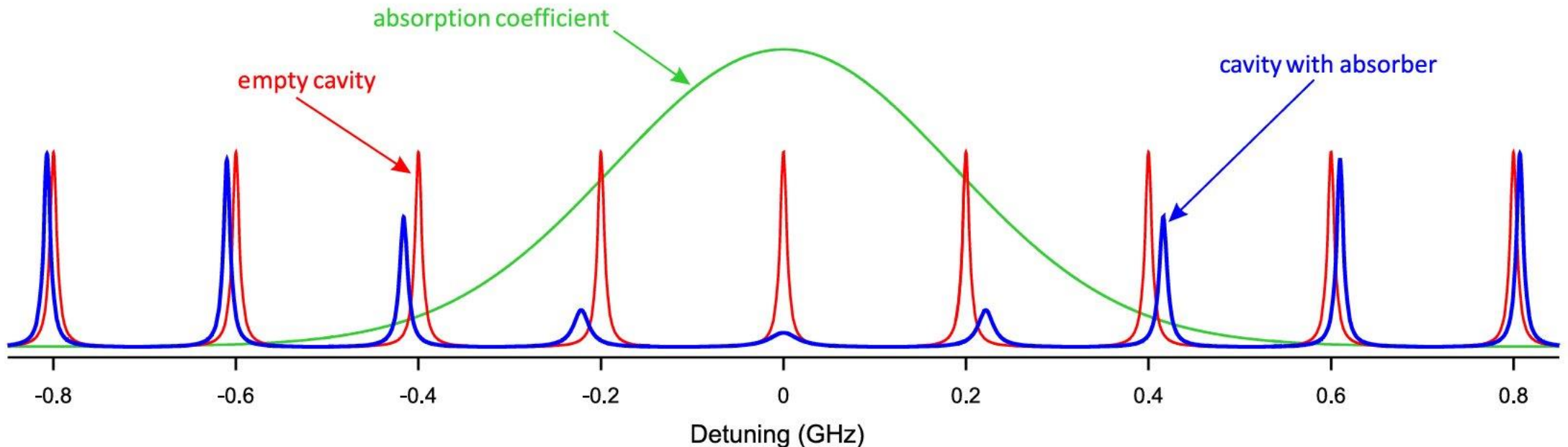
Dispersive heterodyne cavity ring-down spectroscopy exploiting eigenmode frequencies for high-fidelity measurements

Agata Cygan^{*†}, Szymon Wójtewicz, Hubert Józwiak, Grzegorz Kowzan, Nikodem Stolarczyk, Katarzyna Bielska, Piotr Wcisło, Roman Ciuryło, Daniel Lisak[†]

Room for improvement – purely frequency based methods

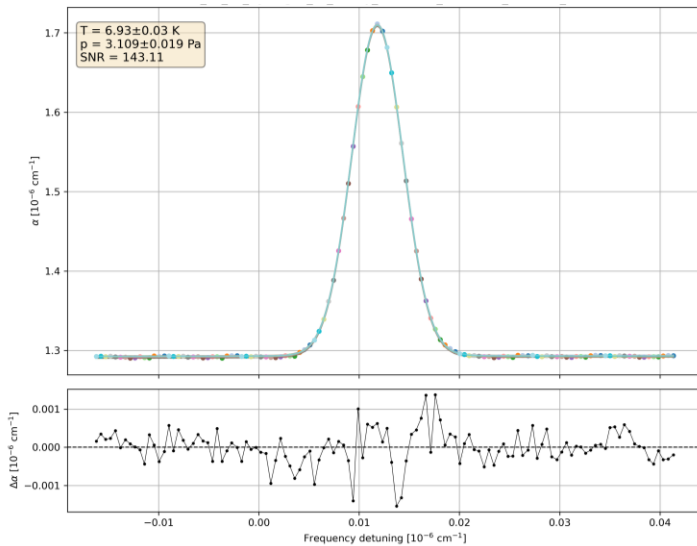


Room for improvement – purely frequency based methods

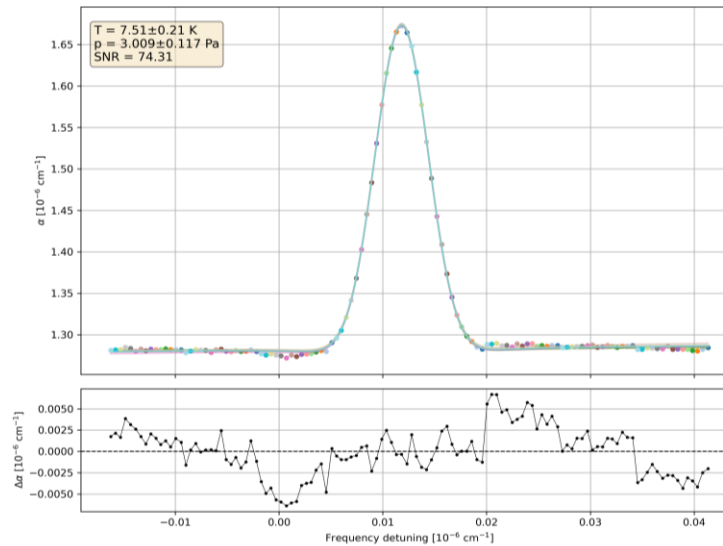


A. Cygan, P. Wcisto, S. Wójtewicz, P. Mastowski, J. Hodges, R. Ciuryło, and D. Lisak, "One-dimensional frequency-based spectroscopy," *Opt. Express* **23**, 14472-14486 (2015).

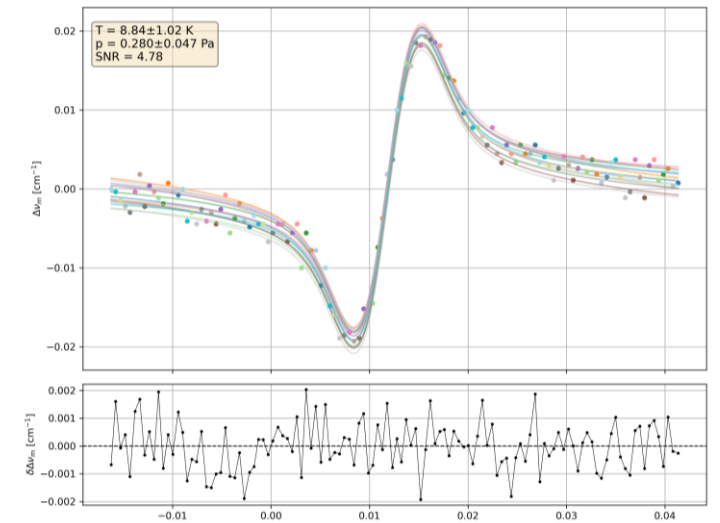
Room for improvement – purely frequency based methods



Cavity Ring Down Spectroscopy (CRDS)



Cavity Mode Width Spectroscopy (CMWS)



Cavity Mode Dispersion Spectroscopy (CMDS)

Conclusions

- Cryogenic cavity for spectroscopy, all optical components cooled down to 4 K

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Conclusions

- Cryogenic cavity for spectroscopy, all optical components cooled down to 4 K
- Clear spectra below 5 K, precise transition energy determination.
- First optical realisation of the primary standard for temperature, concentration and pressure in deep cryogenic conditions.
- Further improvement by implementing FARS and purely frequency based methods.

Contributors



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