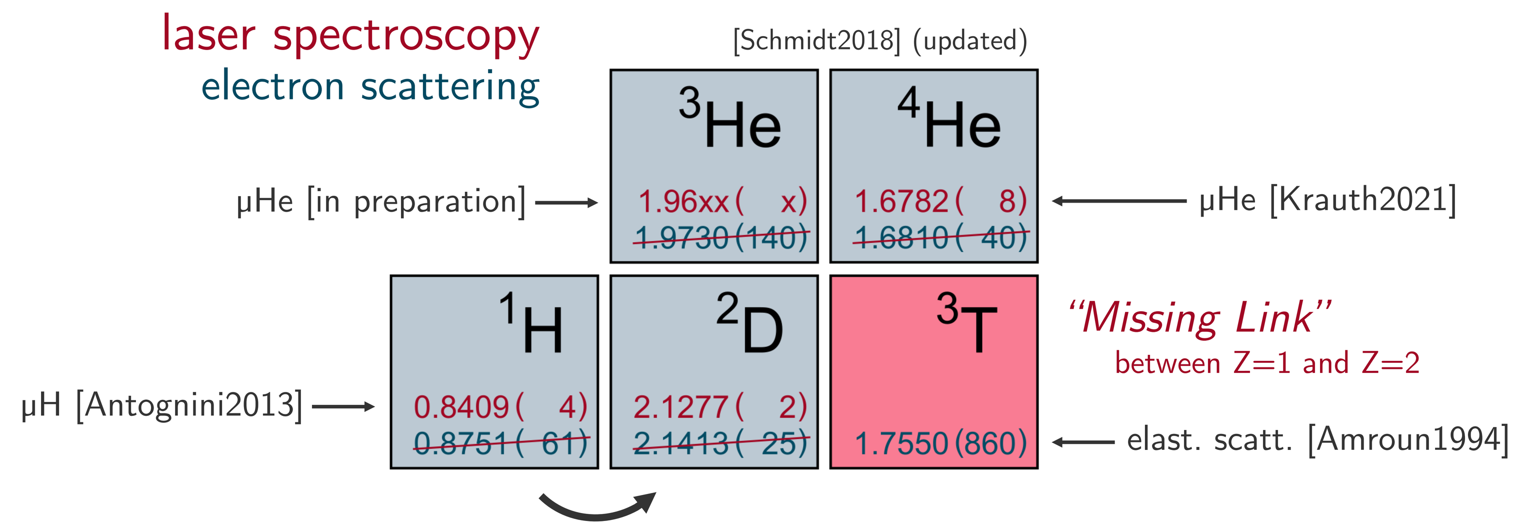
OPTOGALVANIC SPECTROSCOPY OF ATOMIC HYDROGEN

Hendrik Schürg[1], Merten Heppener[1] and Randolf Pohl[1]
[1]Johannes Gutenberg-Universität Mainz, Institut für Physik/QUANTUM & Exzellenzcluster PRISMA+

TOWARDS A MORE PRECISE TRITON RADIUS...

Recent advances on the precision of rms charge radii (all values in fm) of the proton (^{1}H), deuteron (^{2}H), helion (^{3}He) and alpha (^{4}He):

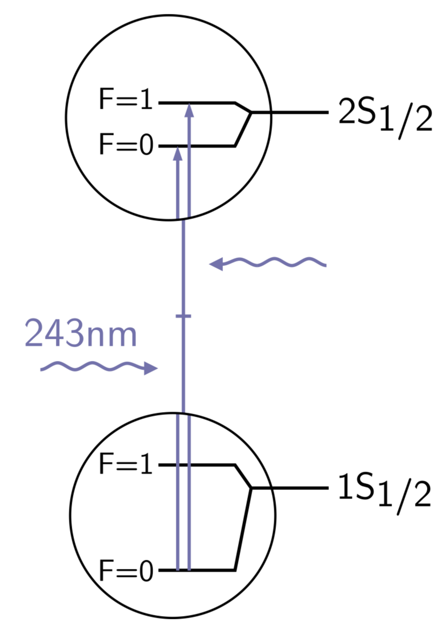


hydrogen-deuterium 1S-2S isotope shift
$\langle r^2\rangle_{^2D} - \langle r^2\rangle_{^1H} = 3.82007(65)\ \mathrm{fm}^2$ [Parthey2010, Jentschura2011]

...analogous: combine high-precision proton charge radius from [Antognini2013] with hydrogen-tritium 1S-2S isotope shift → triton rms charge radius

...USING HYDROGEN/TRITIUM 1S-2S LASER SPECTROSCOPY

- narrow Doppler-cancelling two-photon transitions
- previous high-precision studies on cryogenic atomic beams with H and D at MPQ/Garching, e.g. [Parthey2011]
  - not readily adaptable for tritium (chemical properties, availability and radiation safety)
  - important basis for study of systematic effects
  - detection via induced Lyman-α emission

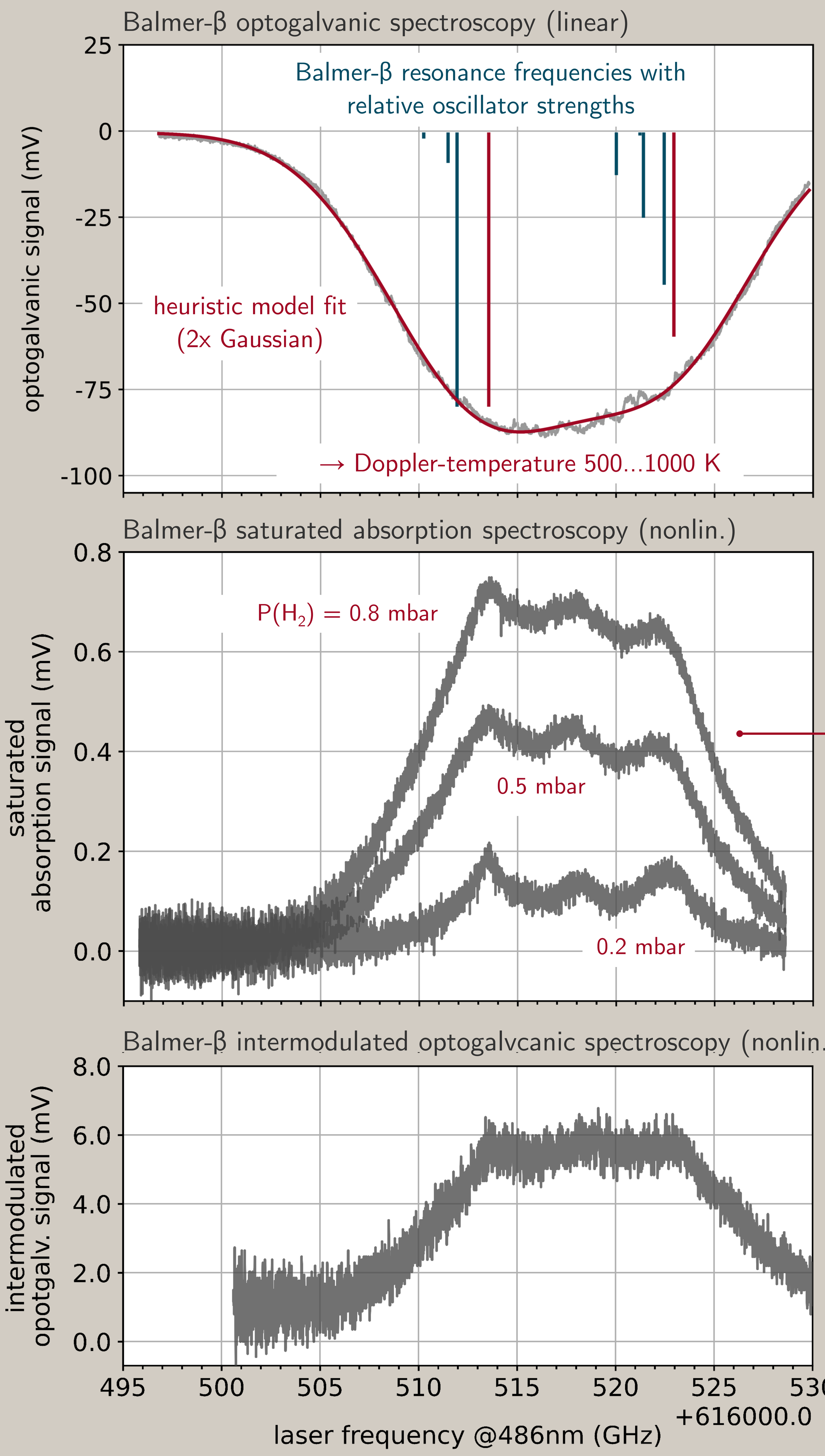


Our approach: Towards (first) results for T(1S-2S) interval via laser optogalvanic spectroscopy *inside* a H/T discharge cell!

Laser-induced changes of state populations in a plasma can be detected via a change of its electrical properties. → [Barbieri1990] (nice overview article)

\+ avoid optical detection within the fluorescence background of the discharge glow
\+ containment of radioactive tritium samples in a *sealed* glass cell
− large systematic effects expected due to electric fields and collision processes

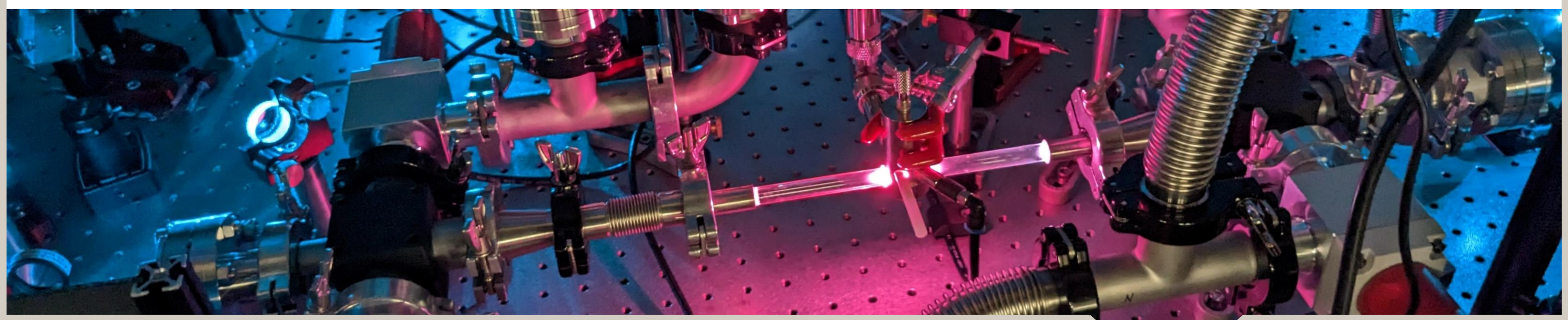
Alternative route: Magnetic trapping of H/D/T via Li buffer gas cooling (currently being developed in our group) [Schmidt2018].



→ at current resolution, no systematic frequency shifts identified

PATHFINDER: BALMER-β LASER SPECTROSCOPY

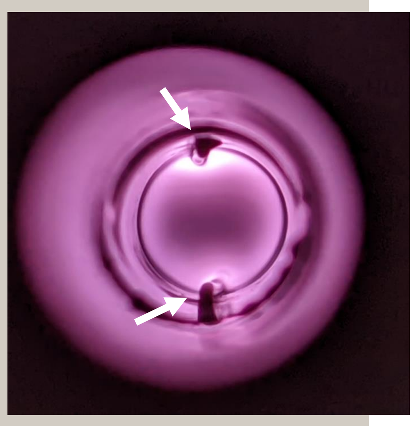
Strong dipole-allowed (one-photon) transitions near 486 nm provide 'playground' for analyzing/optimizing the discharge and testing spectroscopy methods.



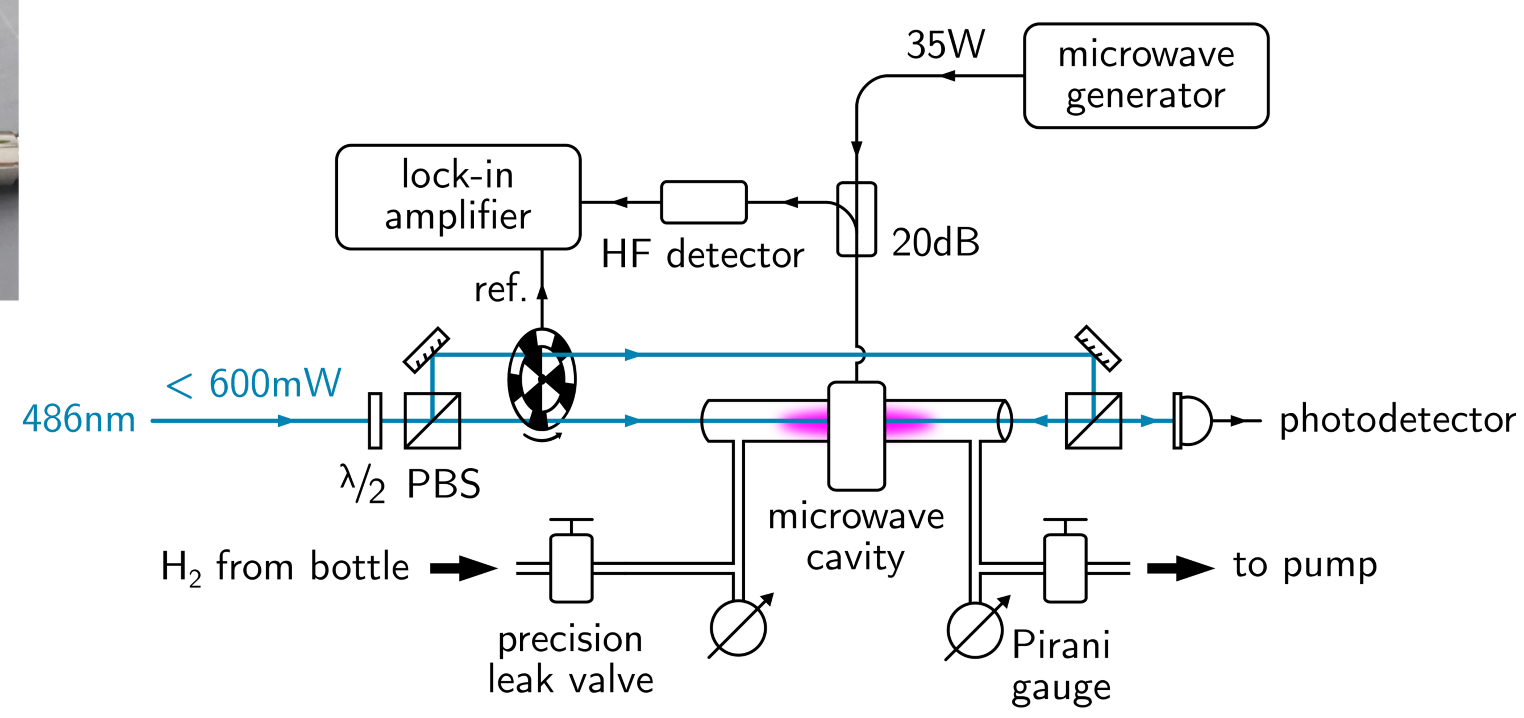
BALMER-β OPTOGALVANIC SPECTROMETER

- (for now) *dynamic* equilibrium at approx. 0.5 mbar H_2 (with flow rates ≈ 0.2 mbar ml/s)
- air-cooled Evenson-type microwave cavity
  - forward power 35 W/ reflected power < 1W
  - very delicate tuning impairs systematic reproduction of discharge conditions
- successful optogalvanic detection via measurement of reflected microwave power (→ probing the impedance of the plasma)
- no improvement with alternative double-electrode detection [Suzuki1983] (→ probing the plasma potentials at two axial tungsten wires)

double-electrodes wires in discharge tube ▾



Evenson-type ▴ microwave cavity



Schematic setup for intermodulated optogalvanic spectroscopy of the hydrogen Balmer-β transitions.

OUTLOOK

- polarization intermodulated excitation (POLINEX) spectroscopy [Hänsch1981] to suppress Doppler-broadened background due to velocity-changing elastic collisions
- evaluation of optogalvanic spectroscopy with radio-frequency hydrogen discharge
- adaptation of setup to 1S-2S transition (esp. implementation of 243 nm enhancement cavity)

References:
[Amroun1994] A. Amroun et al. Nuclear Physics A **579**, 596 (1994)
[Antognini2013] Antognini et al. Science **339**, 417 (2013)
[Barbieri1990] Barbieri et al. Rev. Mod. Phys. **62**, 603 (1990)
[Hänsch1981] Hänsch et al. Optics Comm. **38**, 47 (1981)
[Jentschura2011] Jentschura et al. Phys. Rev. A **83**, 042505 (2011)
[Krauth2021] Krauth et al. Nature **589**, 527 (2021)
[Parthey2010] Parthey et al. Phys. Rev. Lett. **104**, 233001 (2010)
[Parthey2011] Parthey et al. Phys. Rev. Lett. **107**, 203001 (2011)
[Schmidt2018] Schmidt et al. (2018) J. Phys.: Conf. Ser. **1138**, 012010 (2018)
[Suzuki1983] Suzuki et al. Journal de Physique Colloques **44**, C7 (1983)