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Determination of absolute erosion yields and S/XB values via Cavity Ring-Down Spectroscopy in the Pilot-PSI linear device

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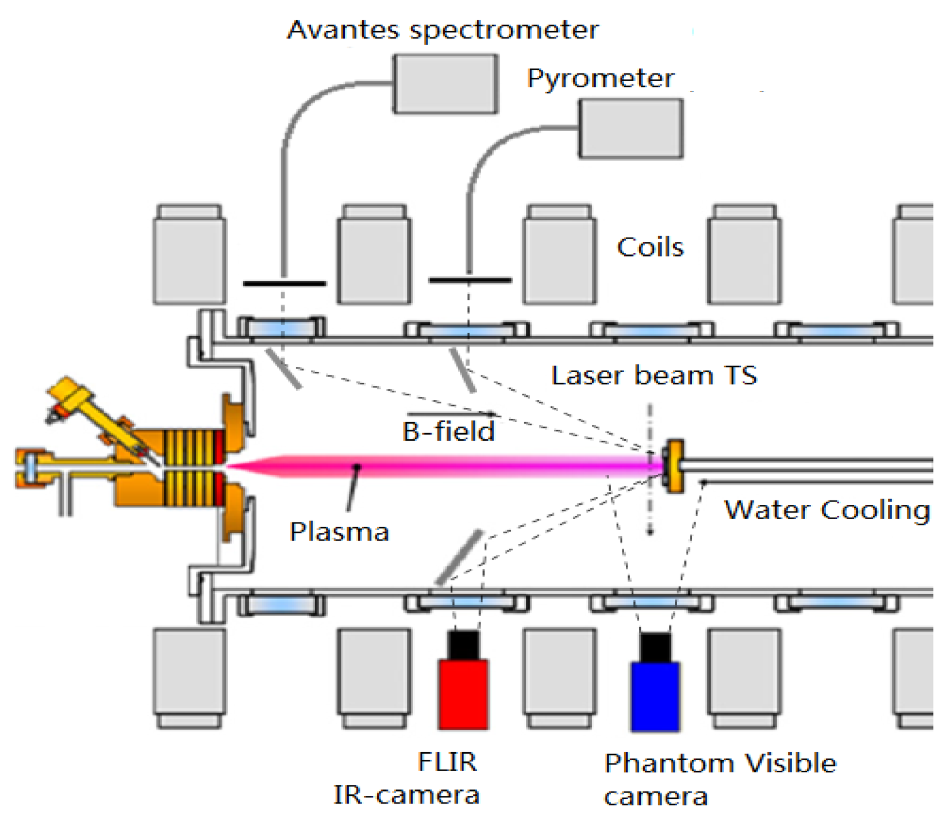
Why liquid metals as candidate for DEMO?

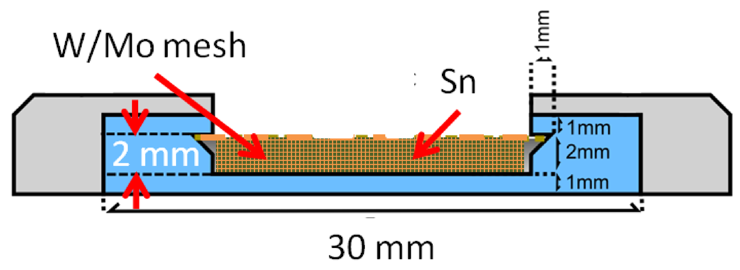
- DEMO exhaust fluxes and operating periods significantly increased compared to ITER [1,2]. → alternative materials investigation.
- Damage and erosion of solid PFC's accumulated over time → regular and time consuming replacement
- Liquid metal (LM) surface can ameliorate these problems:
  - **Replenishment of erosion and "self-healing" surface even after off-normal/transient events**
  - **Liquid flow can convect heat away and use thinner PFC: improved heat removal capability**
  - **"immune" to neutron embrittlement (no lattice)**
- Main candidate materials Li, Sn or Ga due to low melting points

Pilot-PSI: Divertor simulator

- Pilot-PSI[3]: high flux low temperature conditions are a good simulation of the ITER/DEMO divertor

Pilot-PSI
Gases: H, D, He, Ne, N, Ar
T_e 1-3 eV
n_e ~2-3x10^{21} m^{-3}
Heat flux <50 MW m^{-2}
Particle flux ~10^{25} s^{-1}
Ion energy (biasing) 1-150 eV

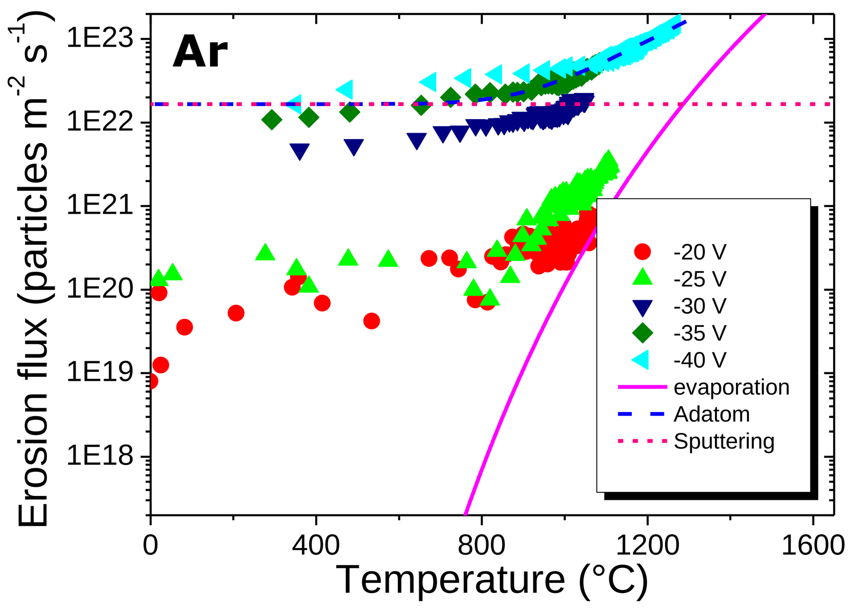


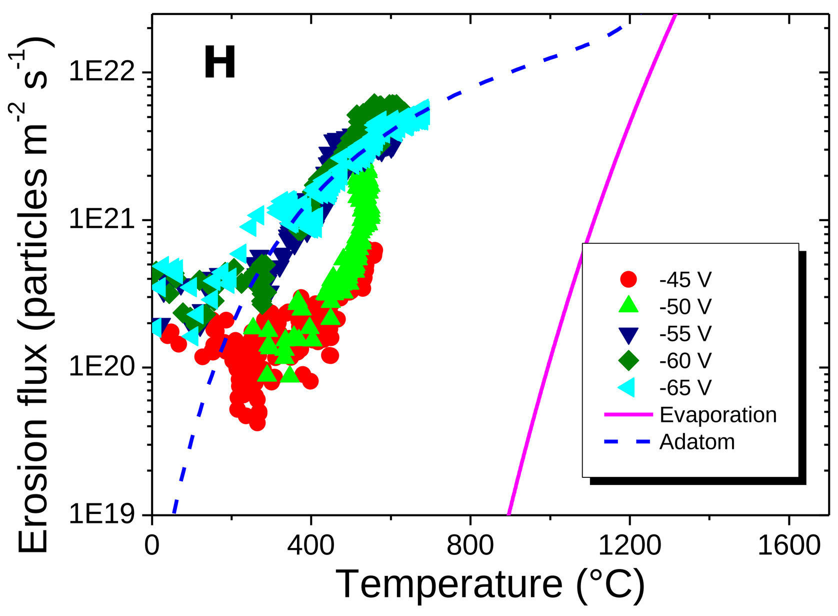


- Targets Sn with W/Mo mesh with size of pores 200-800 μm
- Capillary Porous System (CPS) stops motion of tin due to external forces and replenishes surface

Temperature enhanced erosion not understood

- Many experiments show erosion levels higher than classically expected from evaporation and sputtering at elevated temperatures
- Limitation operating temperature range for liquids?
- Measurements with emission spectroscopy indicate effect, but complicated by assumptions
- Current models do not fully explain observations
- Motivates unambiguous measurement of erosion value via adsorption spectroscopy

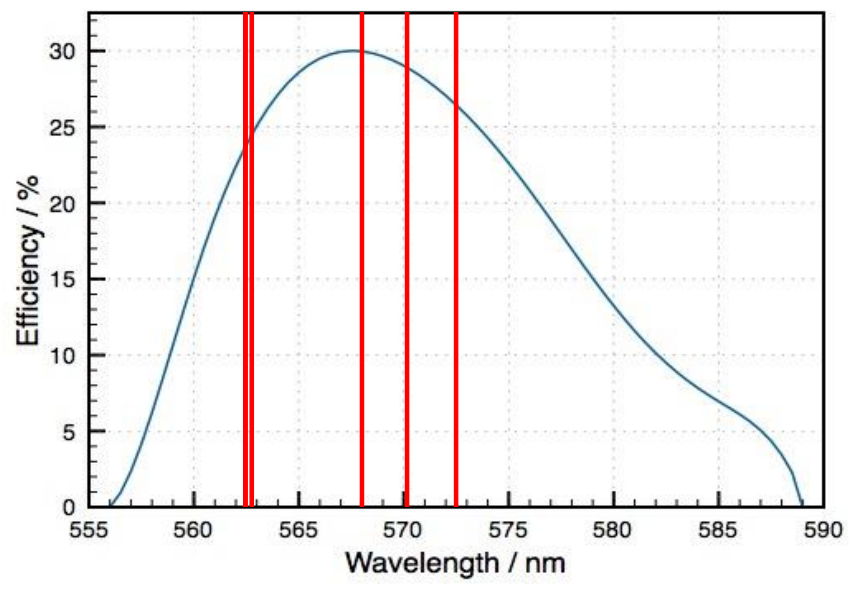


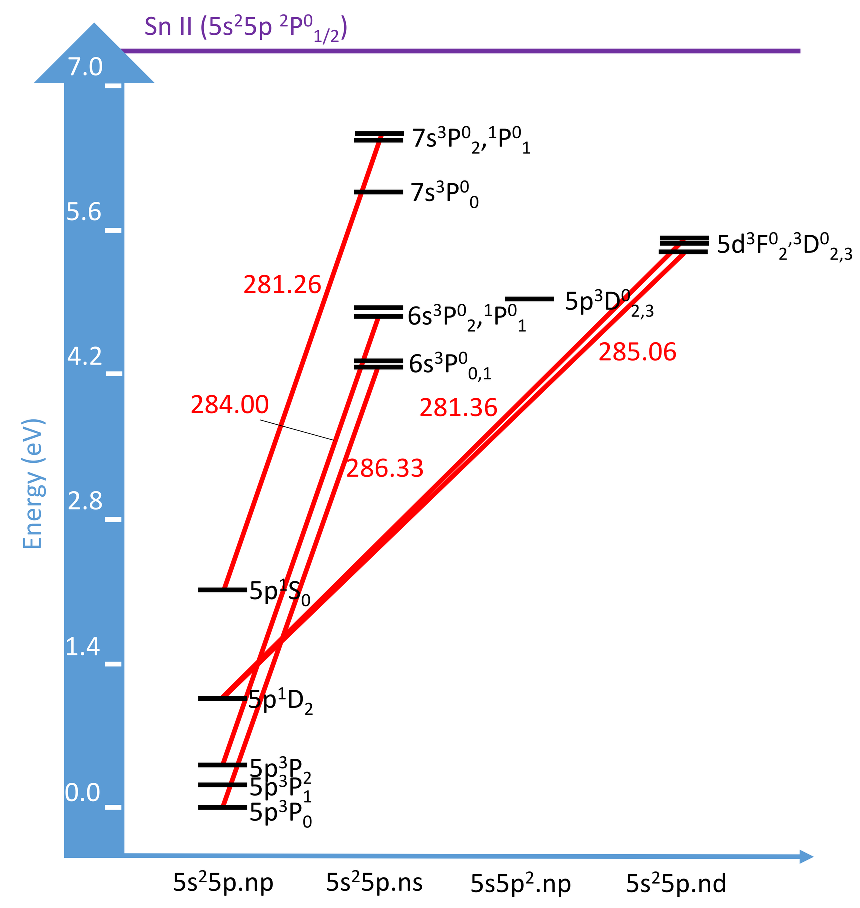


Why CRDS?

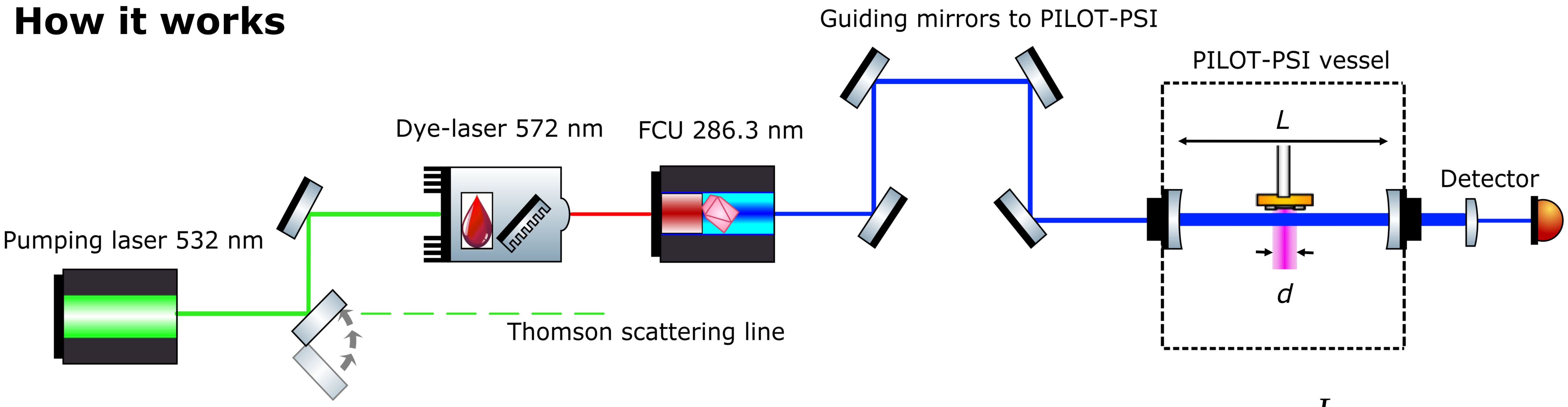
- ✓ Fast measurement speed
- ✓ Long path-length so highly sensitive (down to ppb in near UV range[4])
- ✓ Absolute measurement via absorption (no CR model needed)
- ✓ Immune to shot-to-shot noise
- ✓ Tunable to multiple lines

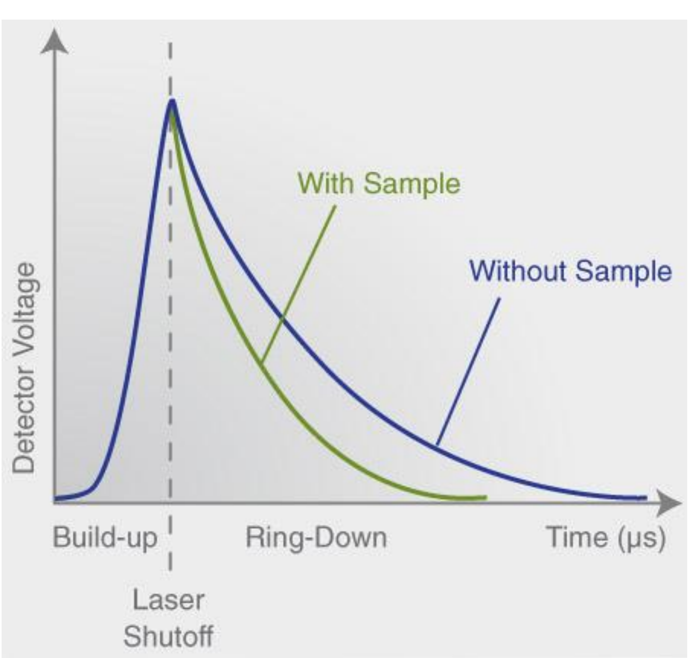
- ✗ Line integrated (inversion)
- ✗ Sensitive to noise/vibrations
- ✗ Need special high reflectivity mirrors





How it works





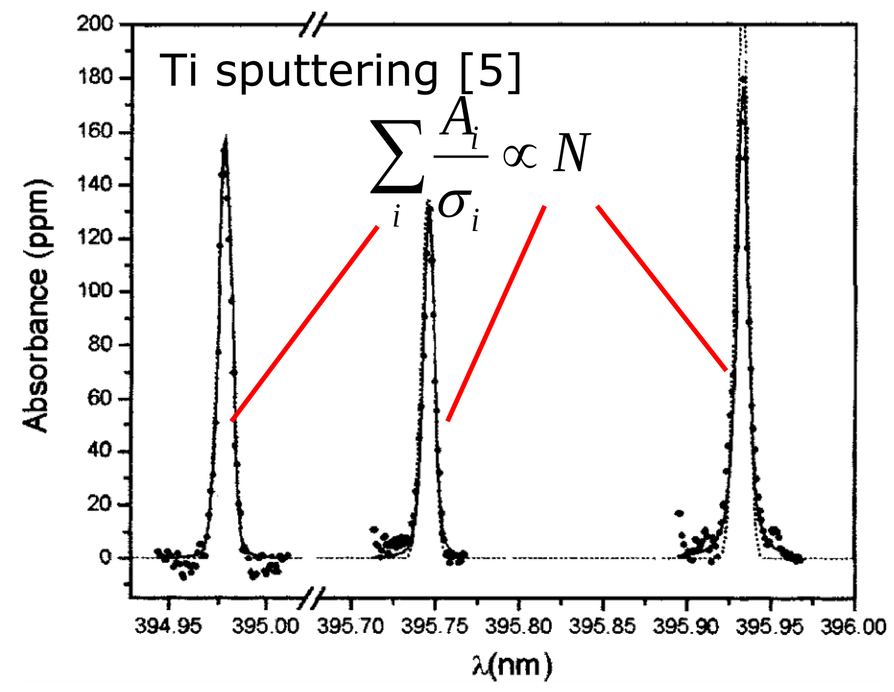
$$I(t) = I_0 \exp\left(-\frac{t}{\tau}\right)$$

$$\tau(\nu) = \frac{L}{c\left[1 - R(\nu) + \sigma(\nu)\int_0^d N(x)dx\right]}$$

- Decay time shorter for higher absorbance of medium (proportional to lower metastable's density)
- Relate to total erosion yield given emission distribution in plasma (spectroscopy/LIF)
- Incorporate lineshape by scanning over linewidth

Outlook

- Can measure absolute erosion yields even in high re-deposition conditions
- Wide variety of candidate materials (different dyes), e.g. W, Li, Ga, etc
- S/XB from relation of particle density and energy to erosion flux from spectroscopy (Abel inversion)



$$\sum_i \frac{A_i}{\sigma_i} \propto N$$

[1] F. Romanelli et al. *Fusion Electricity: A roadmap for the realisation of Fusion Energy* EFDA (2012)
[2] D. Maisonnier et al. Nucl. Fusion **47** (2007) 1524–1532
[3] van Rooij et al. *Appl. Phys. Lett.* **90** (2007) 121501
[4] T. Rienk et al. *Rev. Sci. Instrum.* **66** (1995) 2821
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