Work Function Measurements in BATMAN Upgrade Using LEDs Revealing Remarkably Low Values

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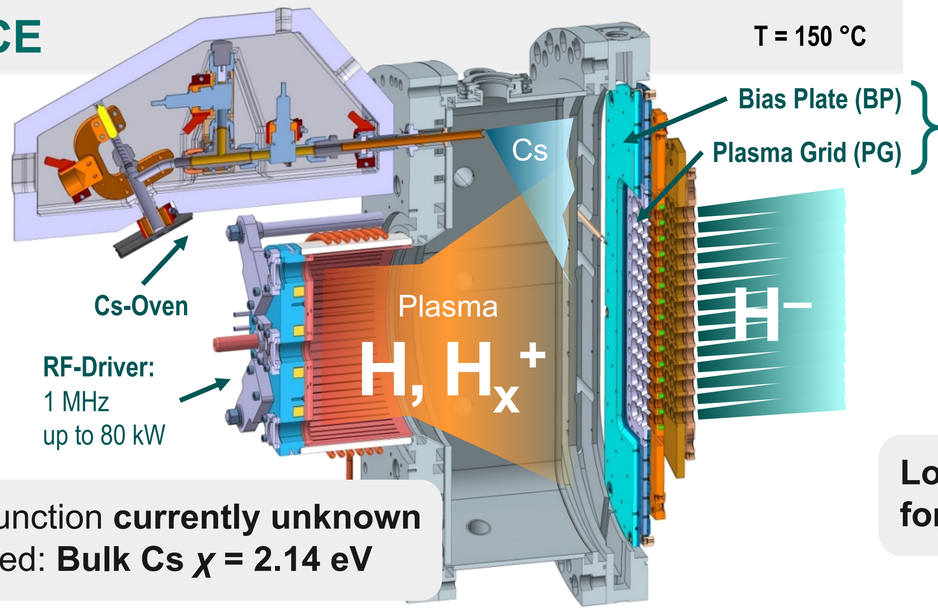
THE BATMAN UPGRADE ION SOURCE

- **Large H^--sources required for ITER NBI**
- **RF-Driver** generates low temperature hydrogen plasma
- Surface conversion reaction:

$$H, H_x^+ + e^- (\text{surface}) \rightarrow H^-$$

- **Low work function** yields high conversion rates
- **Cs evaporated** to lower the work function
- **Ions extracted** through grid system with up to **45 kV**



- Continuous **Cs evaporation**
- **Redistribution** by plasma
- (Vacuum) **Impurities**

→ Work function **currently unknown**
Assumed: **Bulk Cs χ = 2.14 eV**

CAESIUM WORK FUNCTION

- Lowest bulk work function of all elements: **χ = 2.14 eV**
- **Sub-monolayer** coatings result in work function down to **$\chi \approx$ 1.5 eV**
- Formation of **oxidized Cs** adlayer: **Ultra low work function** has been measured for cesium:

  χ = (1.25 ± 0.10) eV*

Low and stable work function needed for high extracted ion current

*A. Heiler, this conference

THE *FOWLER* METHOD

***Fowler*, 1931**: Derivation of the photocurrent I depending on the photon energy E_{ph} and temperature T of a metal surface with work function χ:

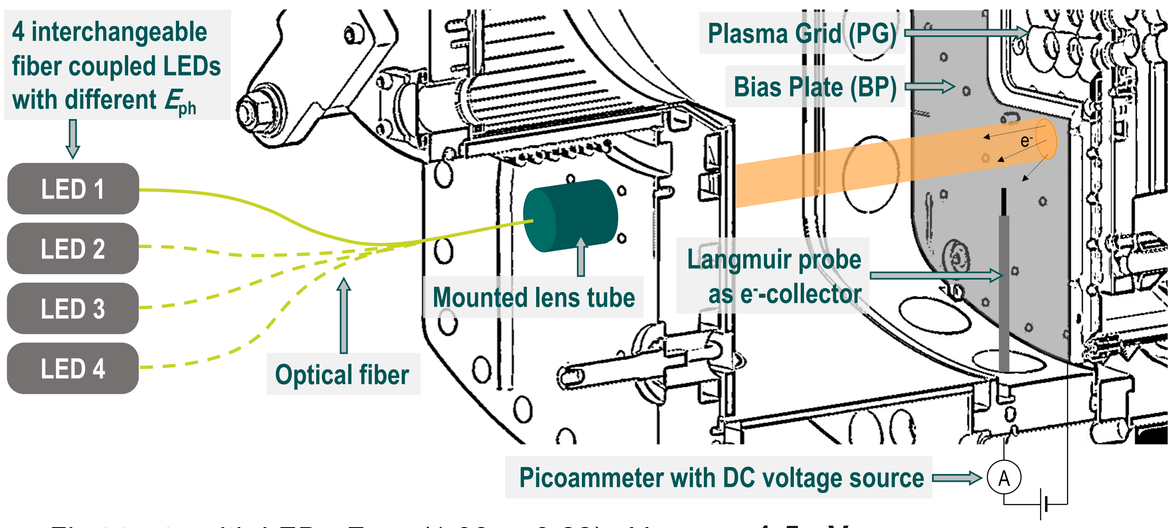
$$I = A\, f\left(\frac{E_{ph}-\chi}{k_B T}\right) \quad \textbf{with} \quad f(k) = \frac{\pi^2}{6} + \frac{1}{2}k^2 - \left[e^{-k} - \frac{1}{2^2}e^{-2k} + \frac{1}{3^2}e^{-3k} - \cdots\right]$$

Measurement of I_{ph} **at different** E_{ph} → **Extrapolation to** χ
But: Measurements only possible during vacuum phase

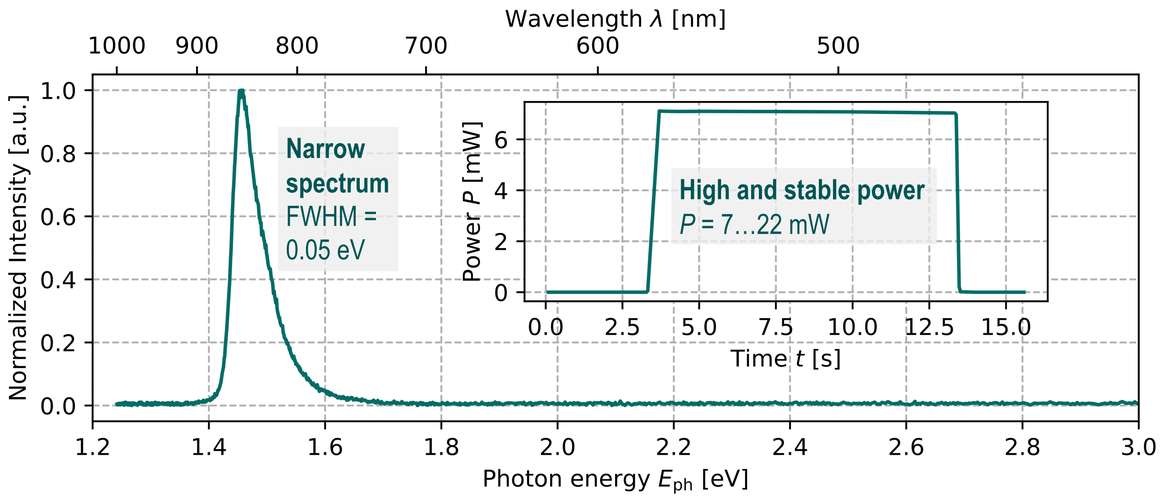
EXPERIMENTAL SETUP

High **noise** and **dark current** → **Strong light source** needed → Novelty: **LEDs**

Difficult **access** → **Fiber coupled**

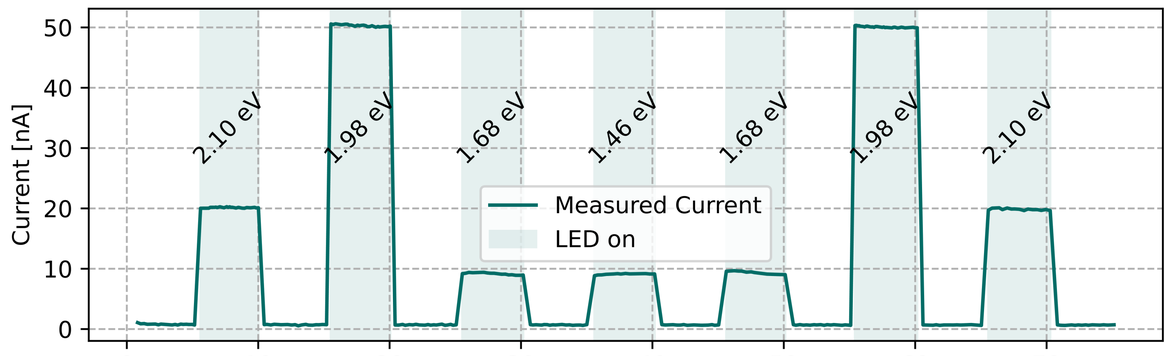


- First **tests** with LEDs E_{ph} = (1.98 … 3.22) eV → **χ < 1.5 eV**
- **Adaption** of LED set to **E_{ph} = (1.46 … 2.10) eV**
- **Quick** measurements: **75** seconds, start **1 minute after plasma pulse**
- **Validation** of LED **spectra**
- Tests with **lower P_{ph}** and varied bias **voltage** → proof of **reliability**
- Benchmark at **ACCesS** → **$\Delta\chi$ = 0.1 eV**
- Exemplary LED **spectrum** and **power trace:**



EVALUATION OF THE MEASURED CURRENTS

Raw data set: Continuous current profile with different LEDs switched on and off

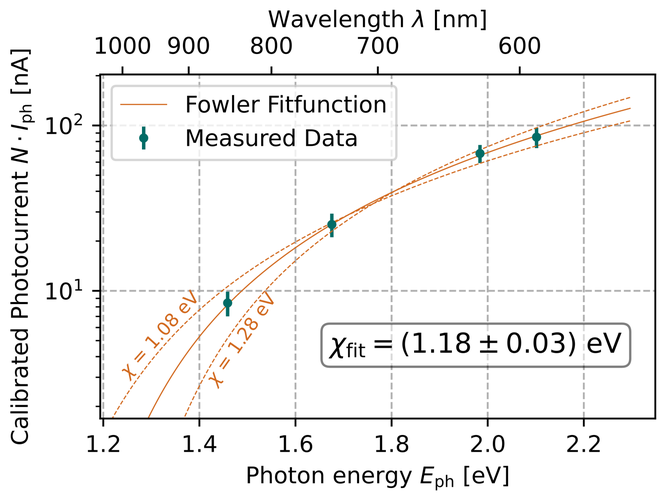


- **Normalization** of the measured photocurrents $I_{ph,i}$ for each wavelength i by the LED photon flux Γ_i, relative to the first LED

$$I_i = I_{ph,i} \cdot N_i$$
$$N_i = \frac{\Gamma_{850nm}}{\Gamma_i}\left(= \frac{P_{850nm}}{P_i}\frac{E_i}{E_{850nm}}\right)$$

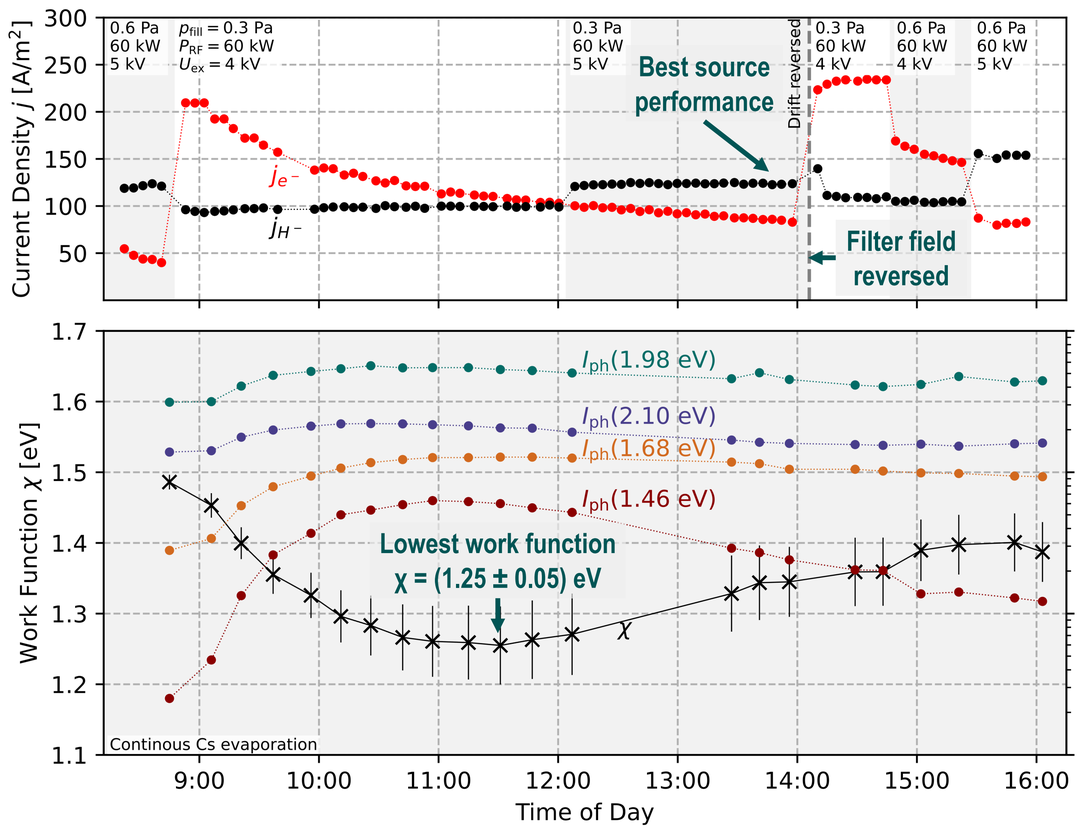
- **Iterative** routine to **consider spectra** of LEDs for Fowler fit

$$I_{ph} = A\, f\left(\frac{E_{ph}-\chi}{k_B T_{BP}}\right)$$



CONTINUOUS MONITORING

Observation of the work function during typical source conditioning



- **Low work function** demonstrated
- **Quickly in a low regime,** lowest after 3 hours: **χ = (1.25 ± 0.05) eV**
- **No asymmetry** of work function, **reversed filter field** → no influence on χ
- Work function **robust under parameter variations**
- Strong **variation of photocurrents**
- **Extracted ion current and vacuum work function in some cases uncorrelated**

CONCLUSION

- **Proof of concept** for WF measurements **inside a negative ion source**
- **Proof of concept** for WF measurements **using LEDs**
- Lowest BP work function significantly below χ = 2.14 eV assumption : **$\chi_{min} \approx$ 1.2 eV**
- **Conditioning:** Work function **quickly in a low regime** and decreasing within hours
- Available for further **systematic measurements**

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