The electron density in an EUV-generated plasma in hydrogen

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Where innovation starts

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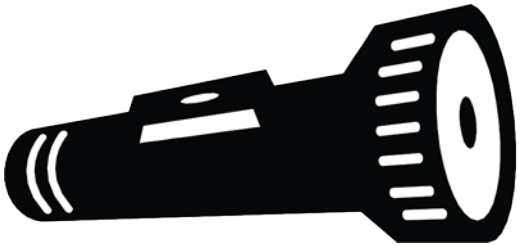
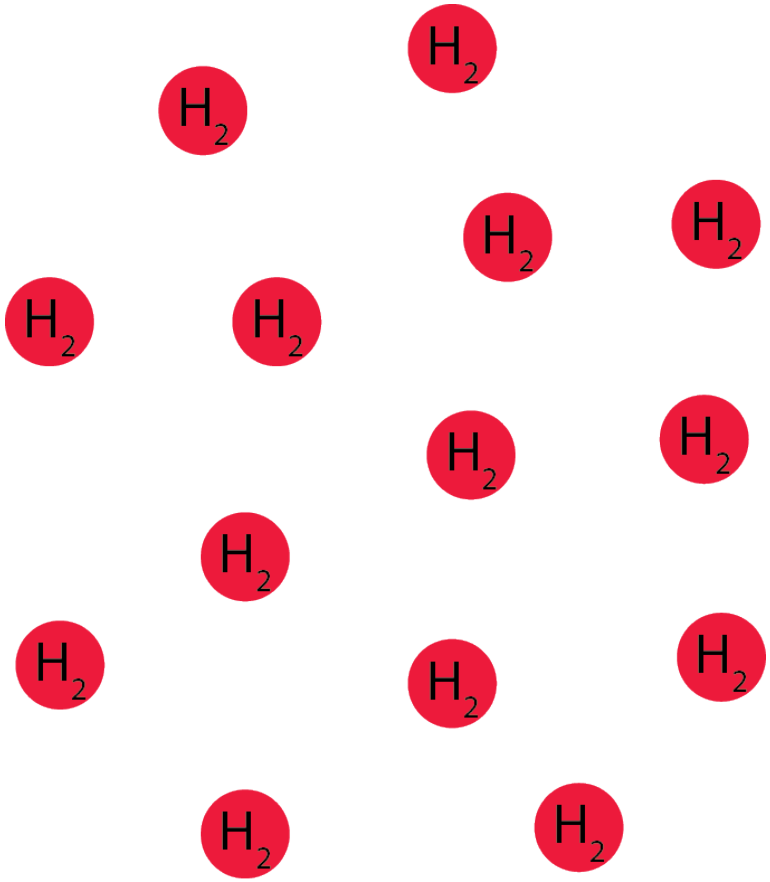
Plasma generation

13.5 nm ≙ 92 eV





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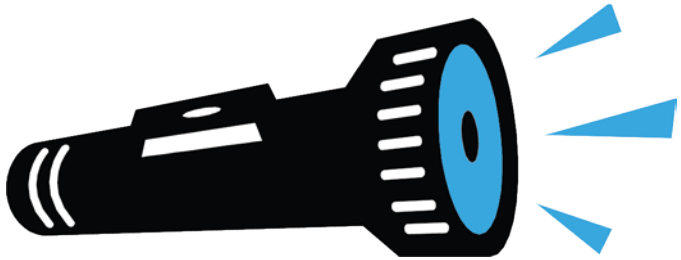
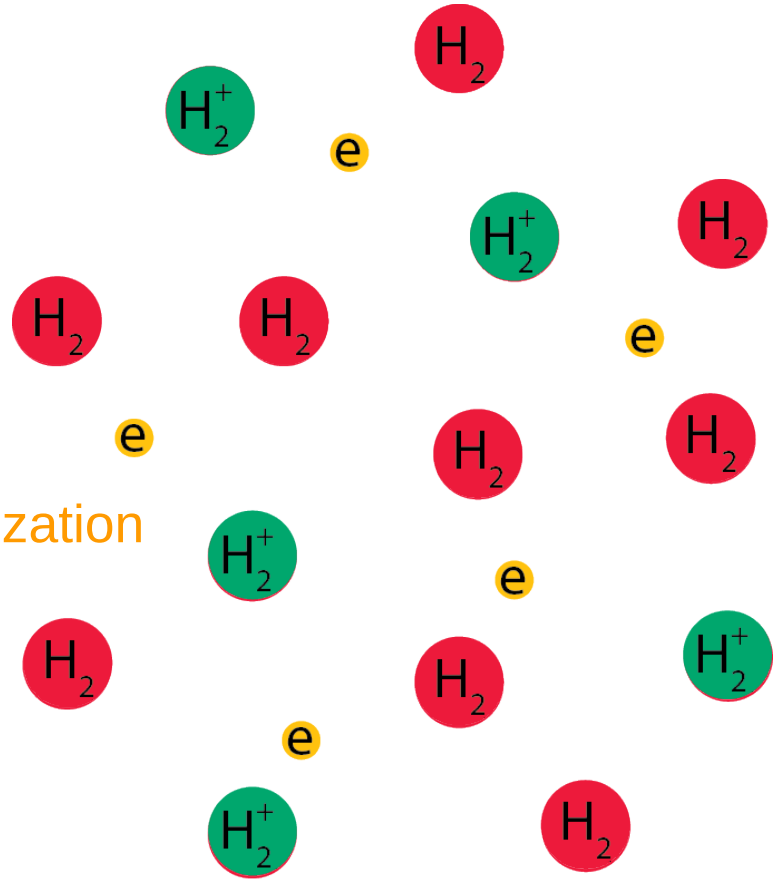


photo-ionization



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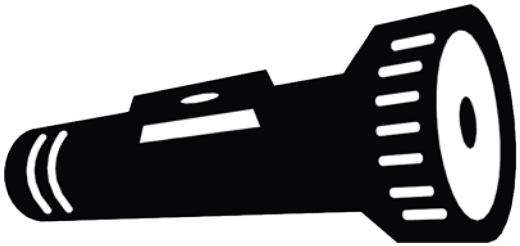

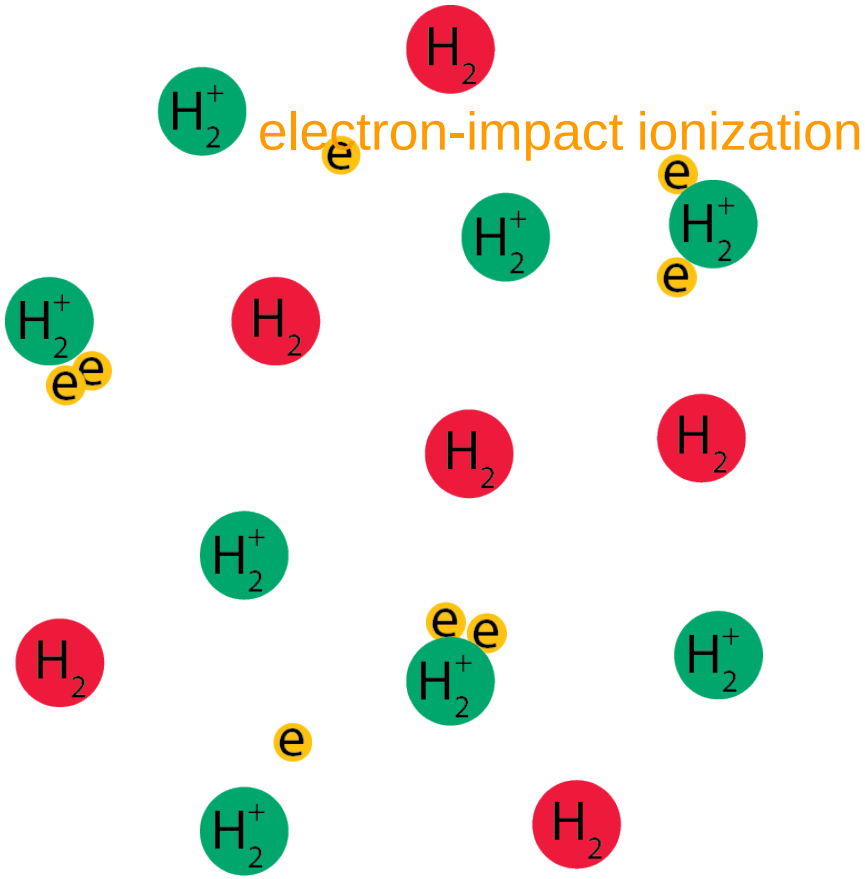

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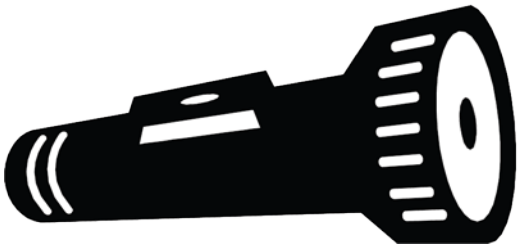

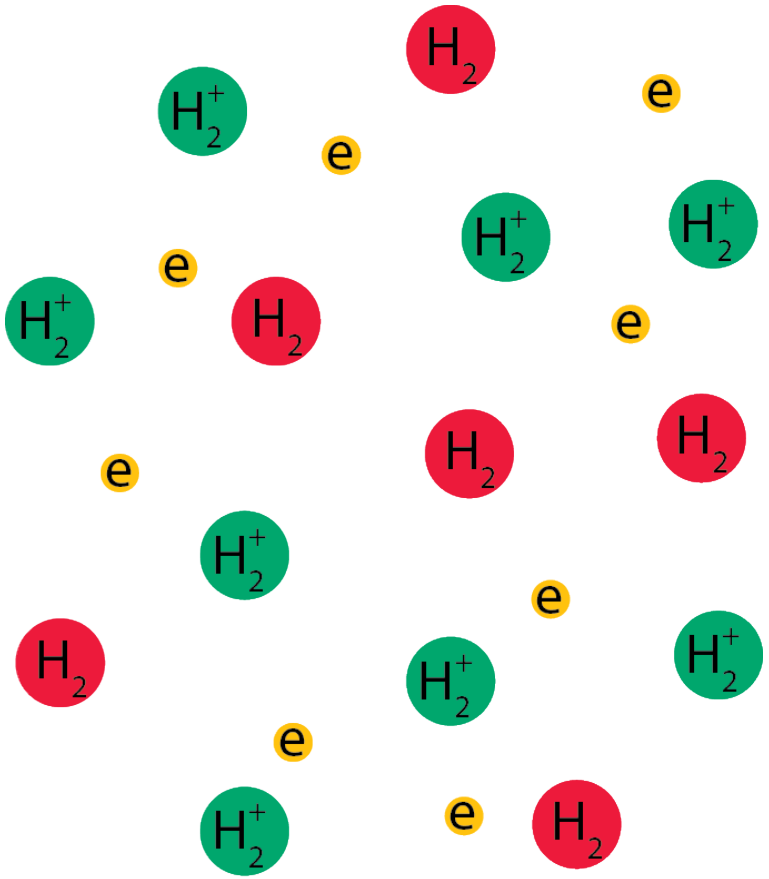

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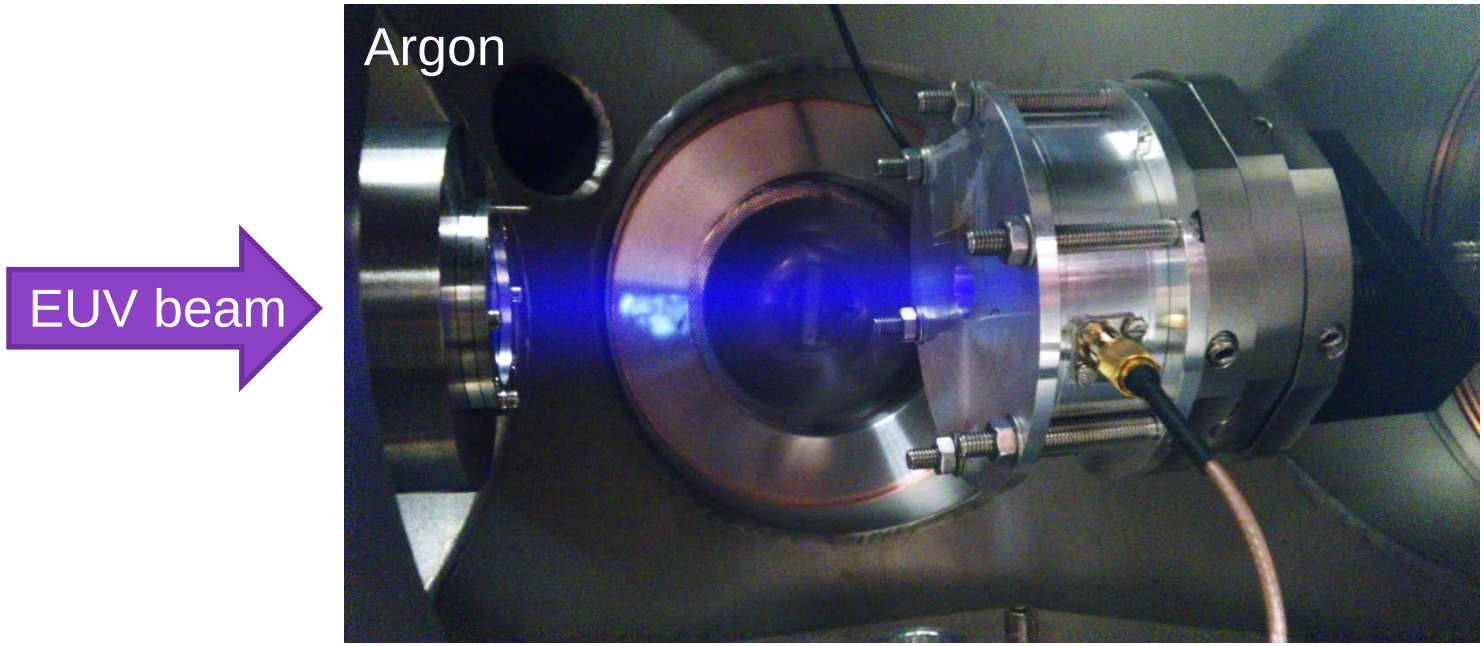
EUV induced plasma

- EUV beam ionizes background gas



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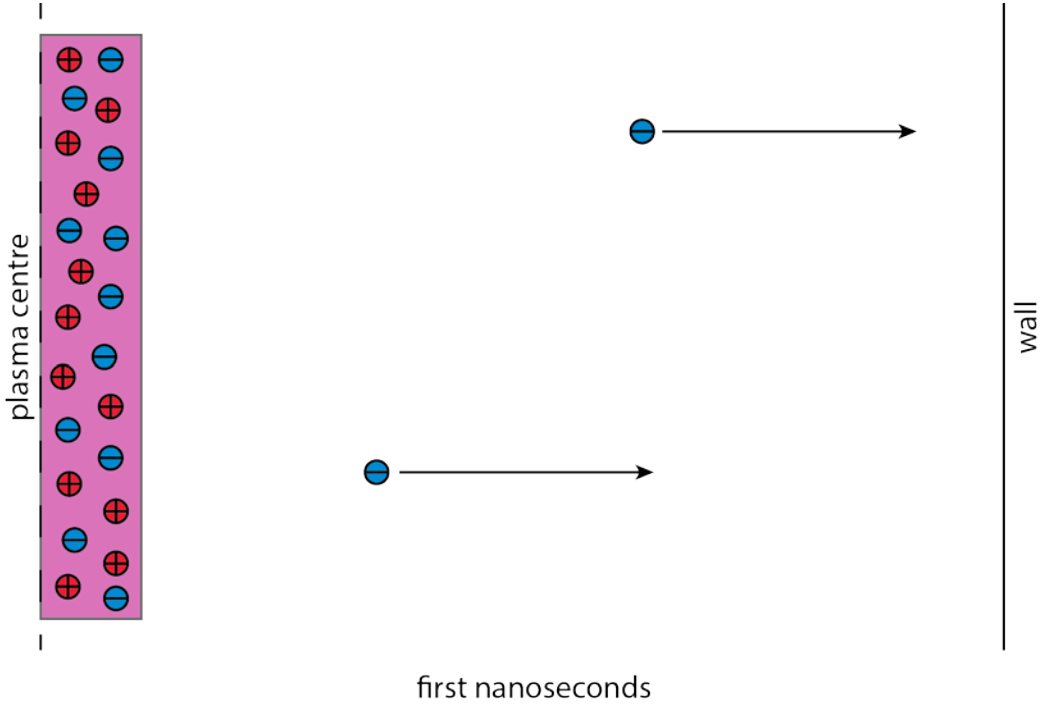
Plasma decay

- Electrons escape (few nanoseconds)



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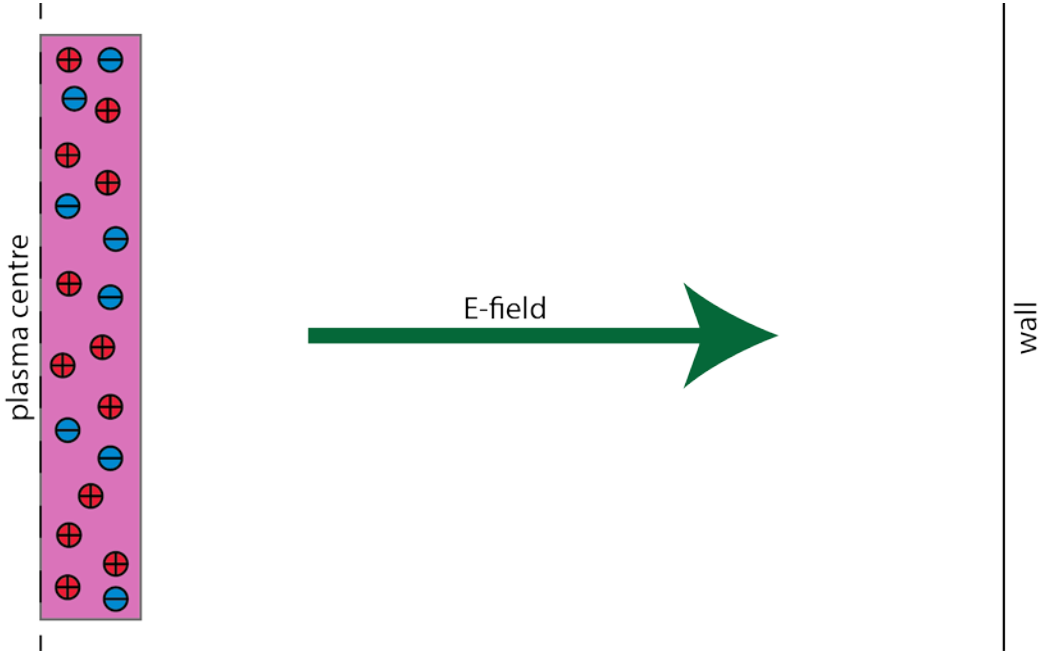
Plasma decay

- Electrons escape (few nanoseconds)
- E-field generated



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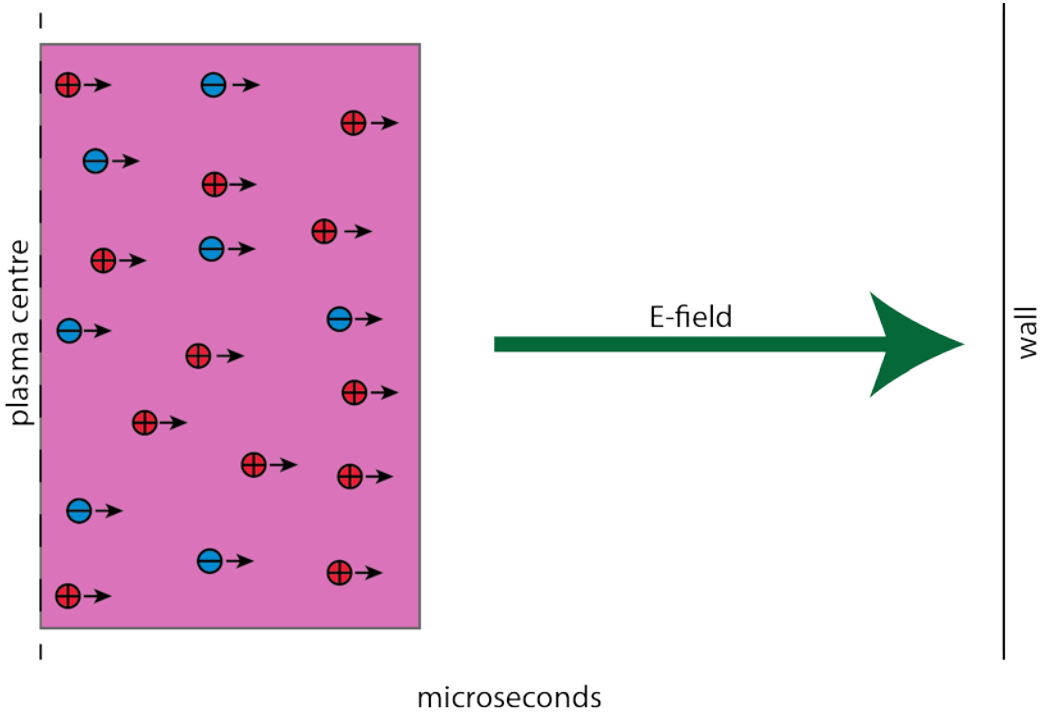
Plasma decay

- Electrons escape (few nanoseconds)
- E-field generated
  - Electron decelerated
  - Ions accelerated
  - Plasma expansion



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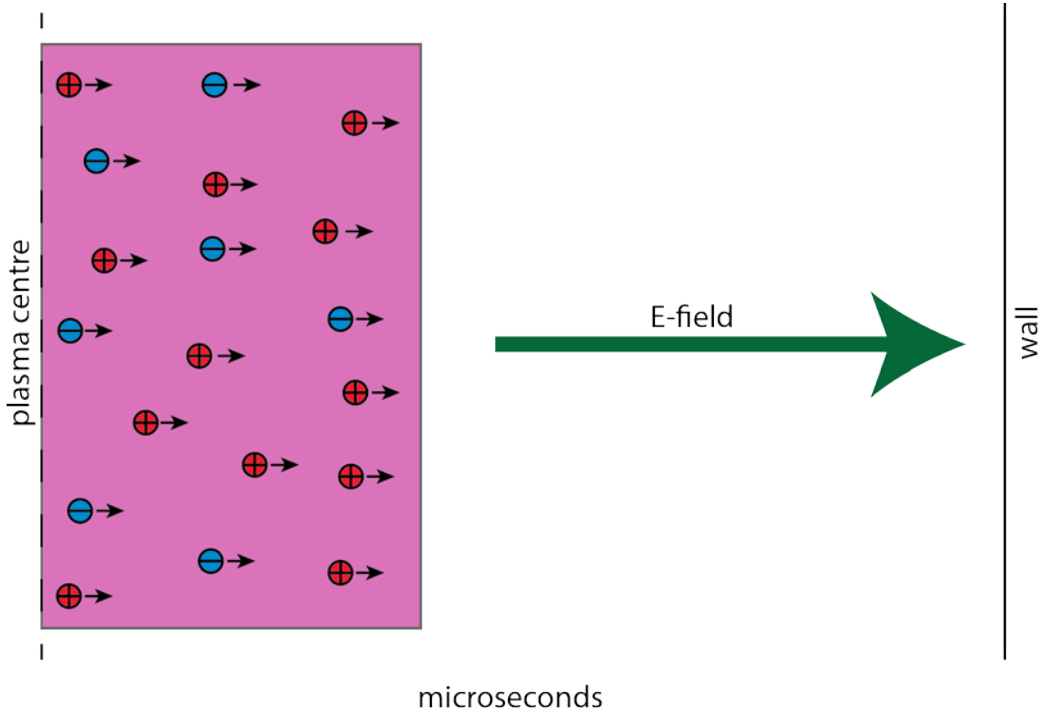
Plasma decay

- Electrons escape (few nanoseconds)
- E-field generated
  - Electron decelerated
  - Ions accelerated
  - Plasma expansion
- Ambipolar flow



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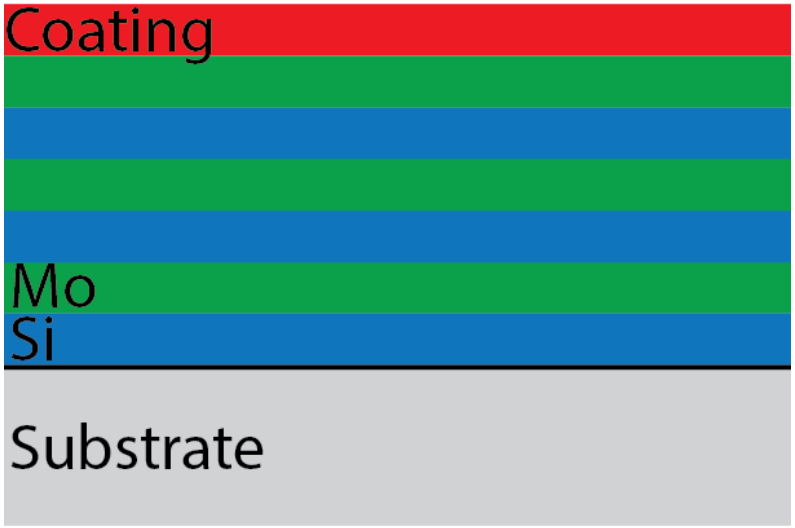
Why is this interesting?



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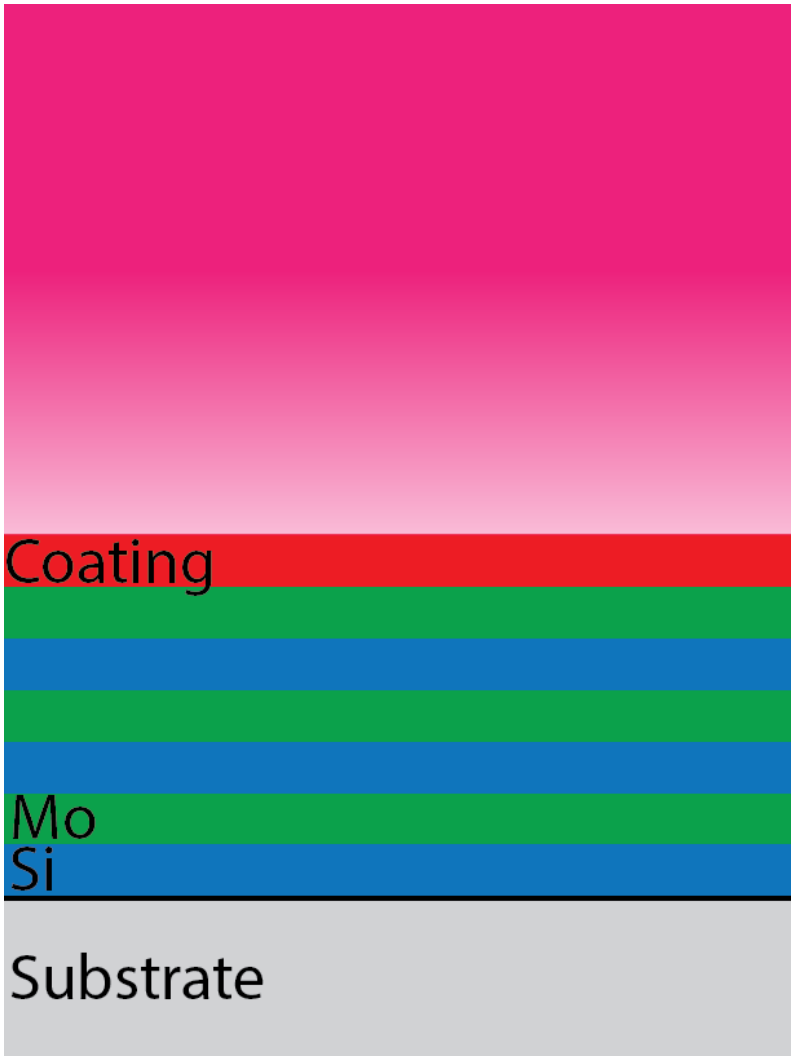

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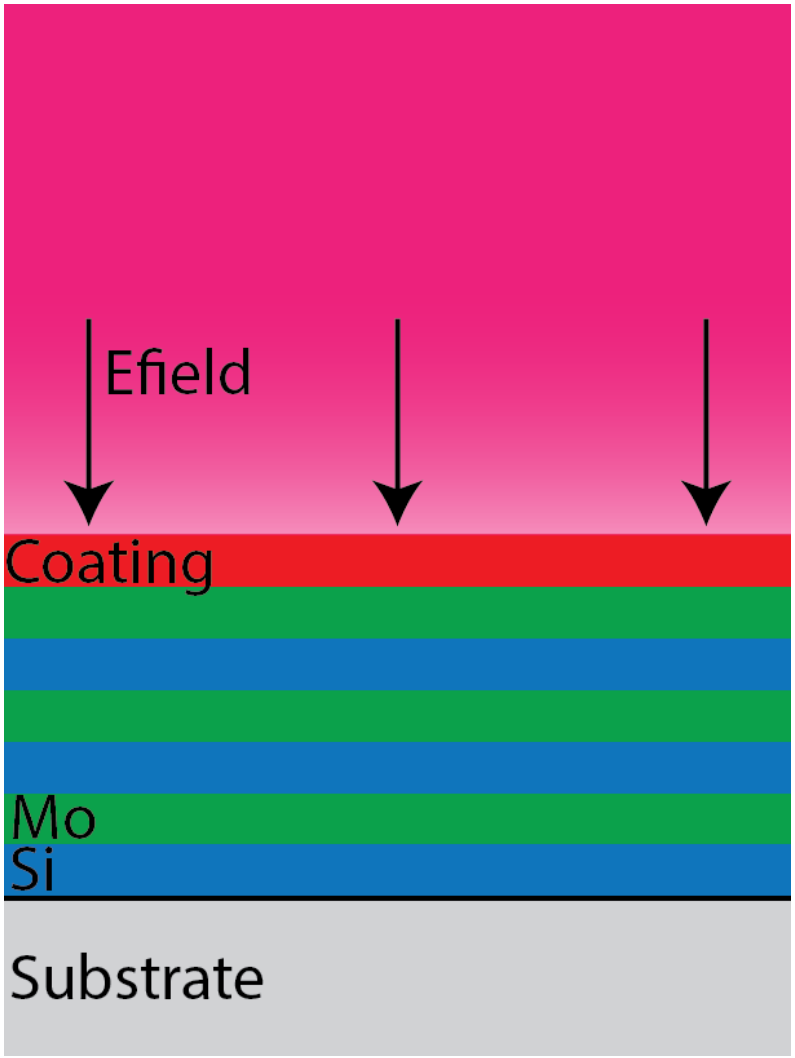

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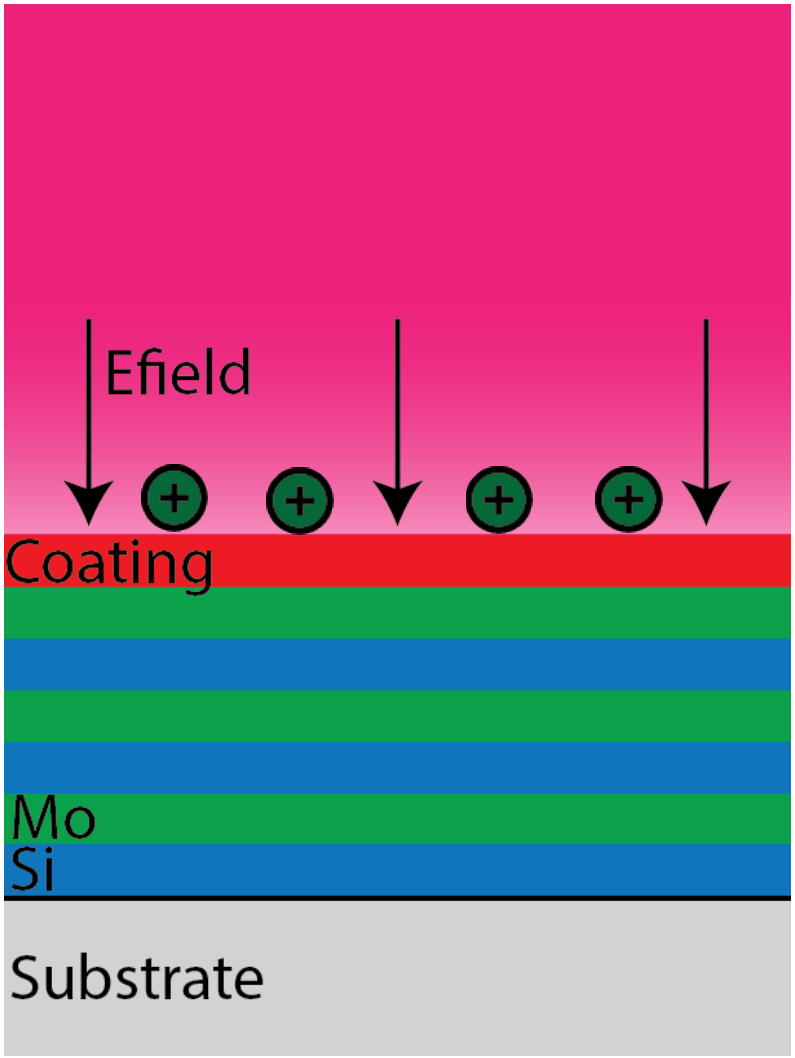

- Long term impact

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Goal

- Gain insight in EUV induced plasma
- Measure electron density:
  - Pressure dependence
  - Repetition rate dependence
  - Spectral dependence

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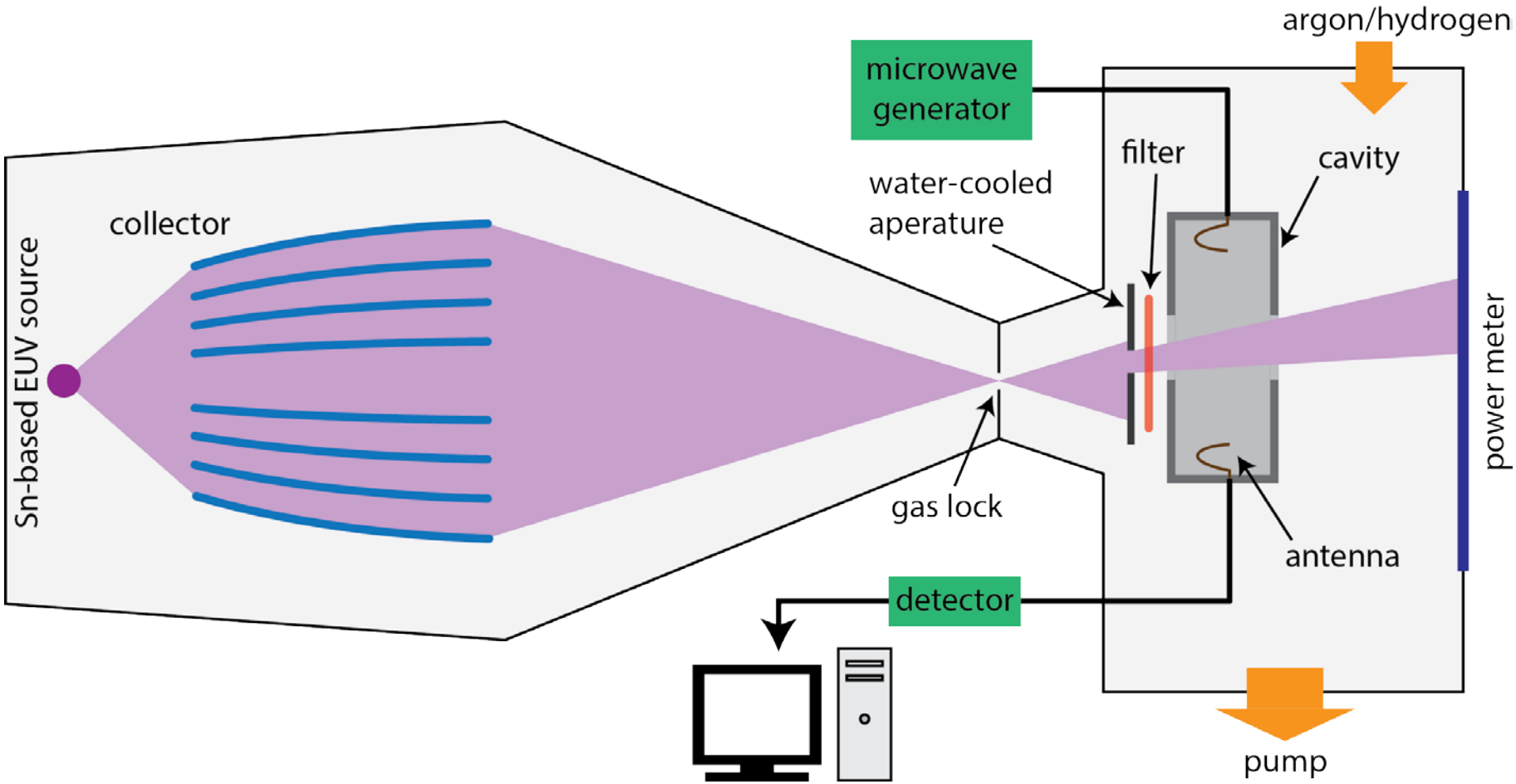
Experimental setup



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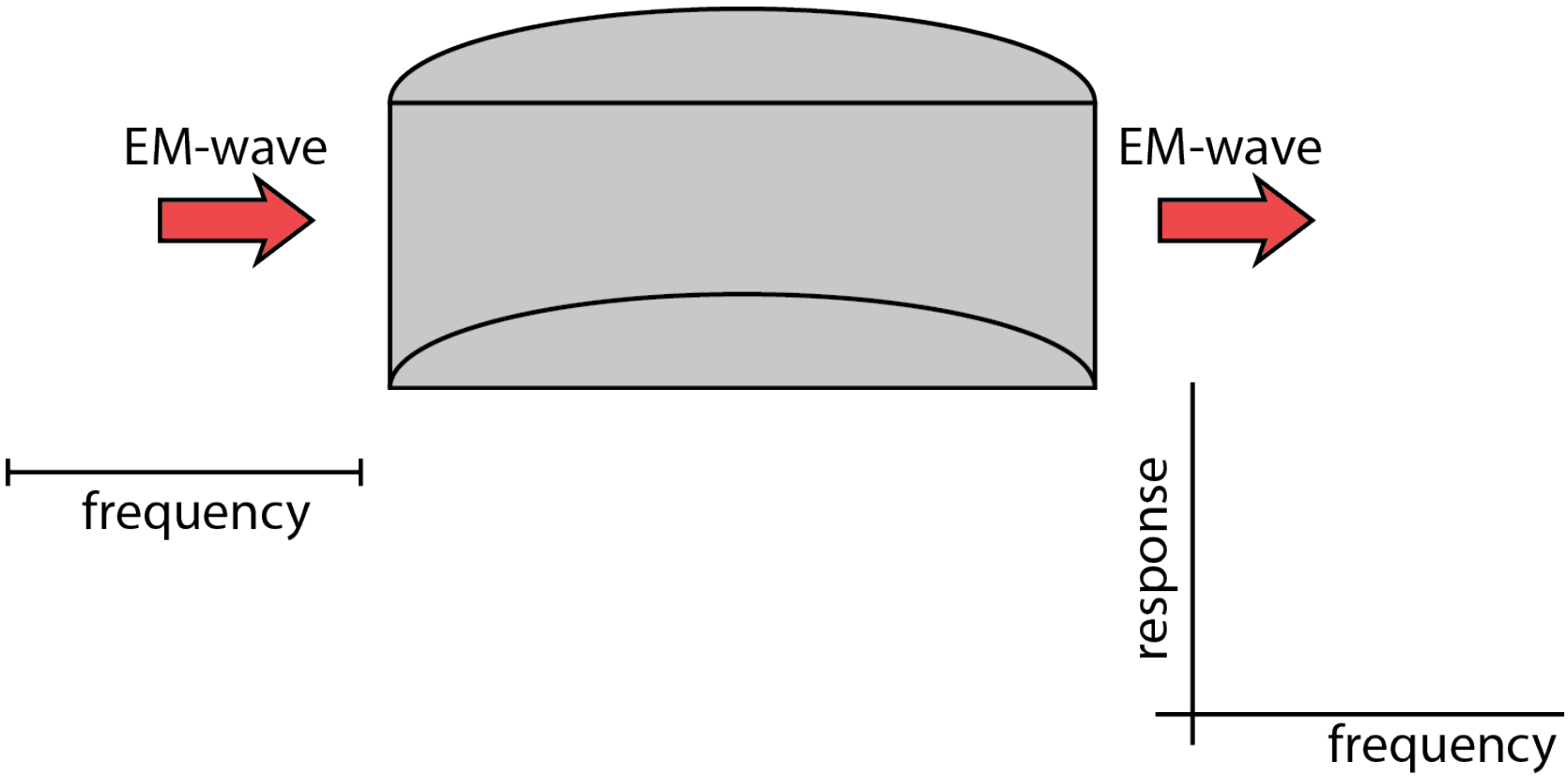
Experimental method



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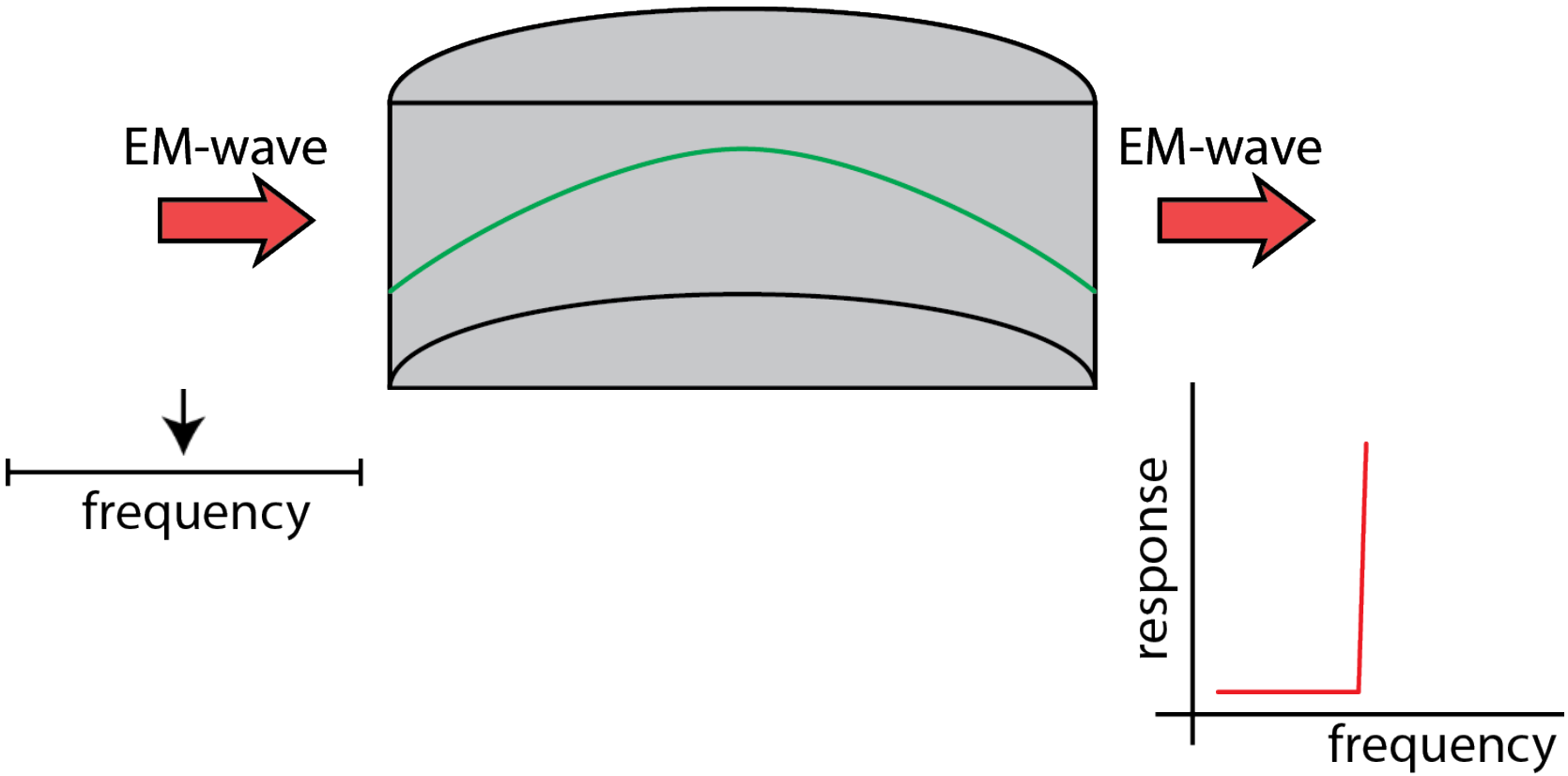

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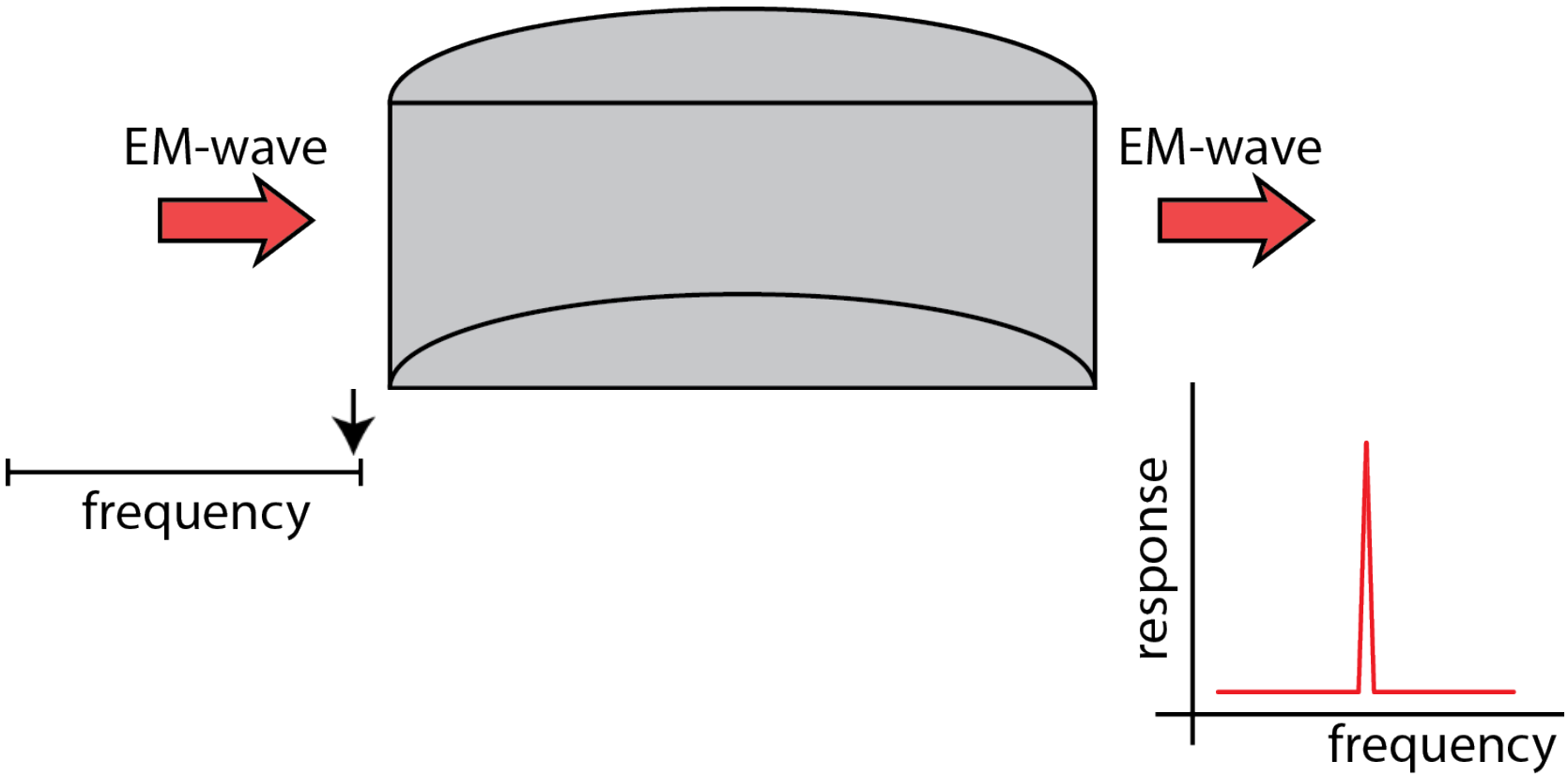

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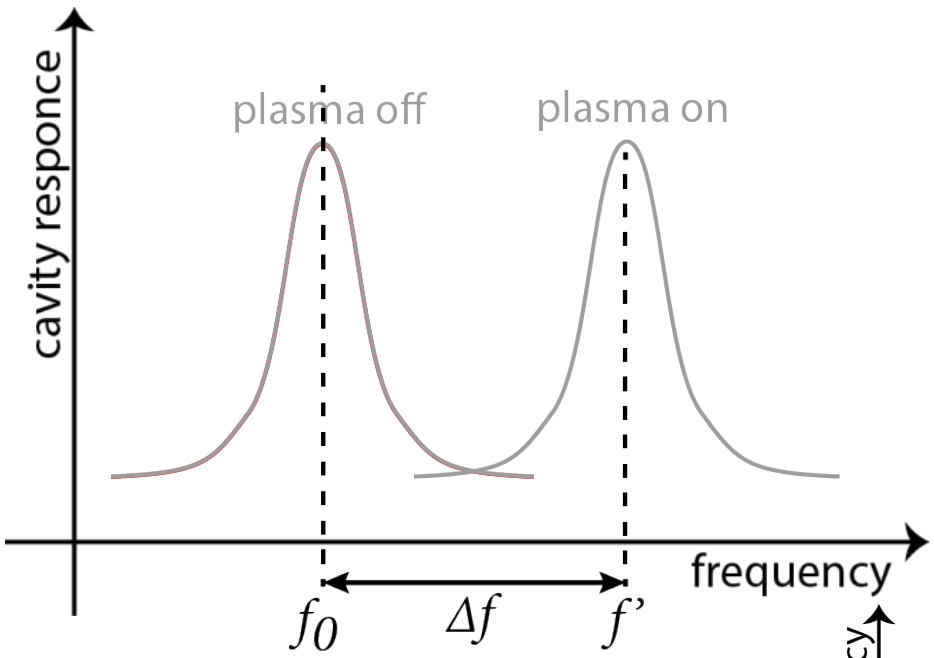
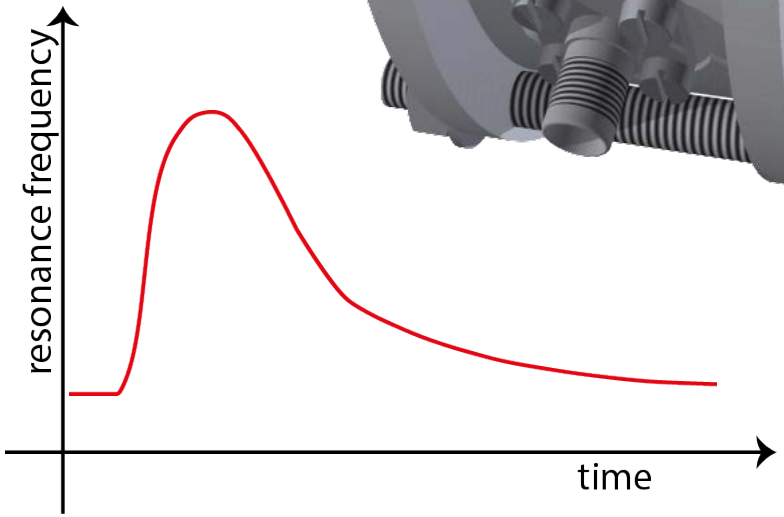


$$\bar{n}_e = \frac{8\pi^2 m_e \varepsilon_0 f'^2}{e^2} \frac{\Delta f}{f_0}$$

$$\bar{n}_e = \frac{\int_{cavity} n_e \cdot E^2 dV}{\int_{cavity} E^2 dV}$$



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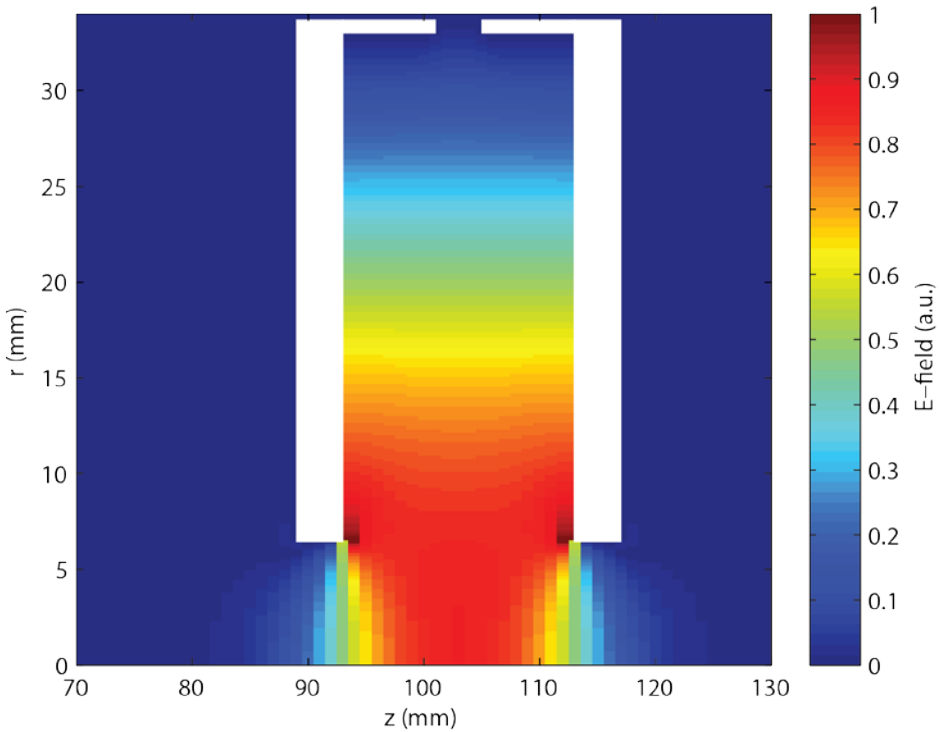

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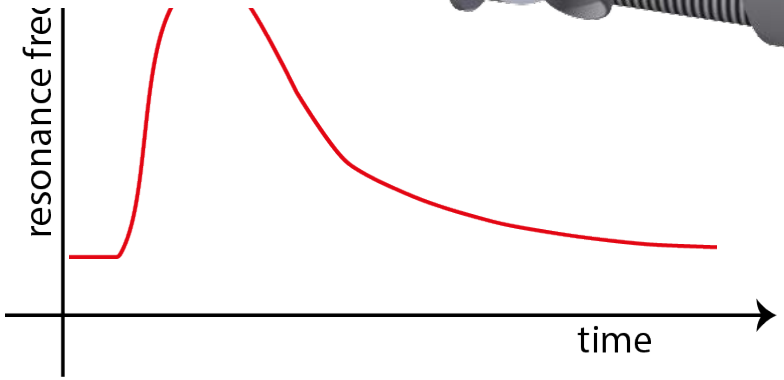

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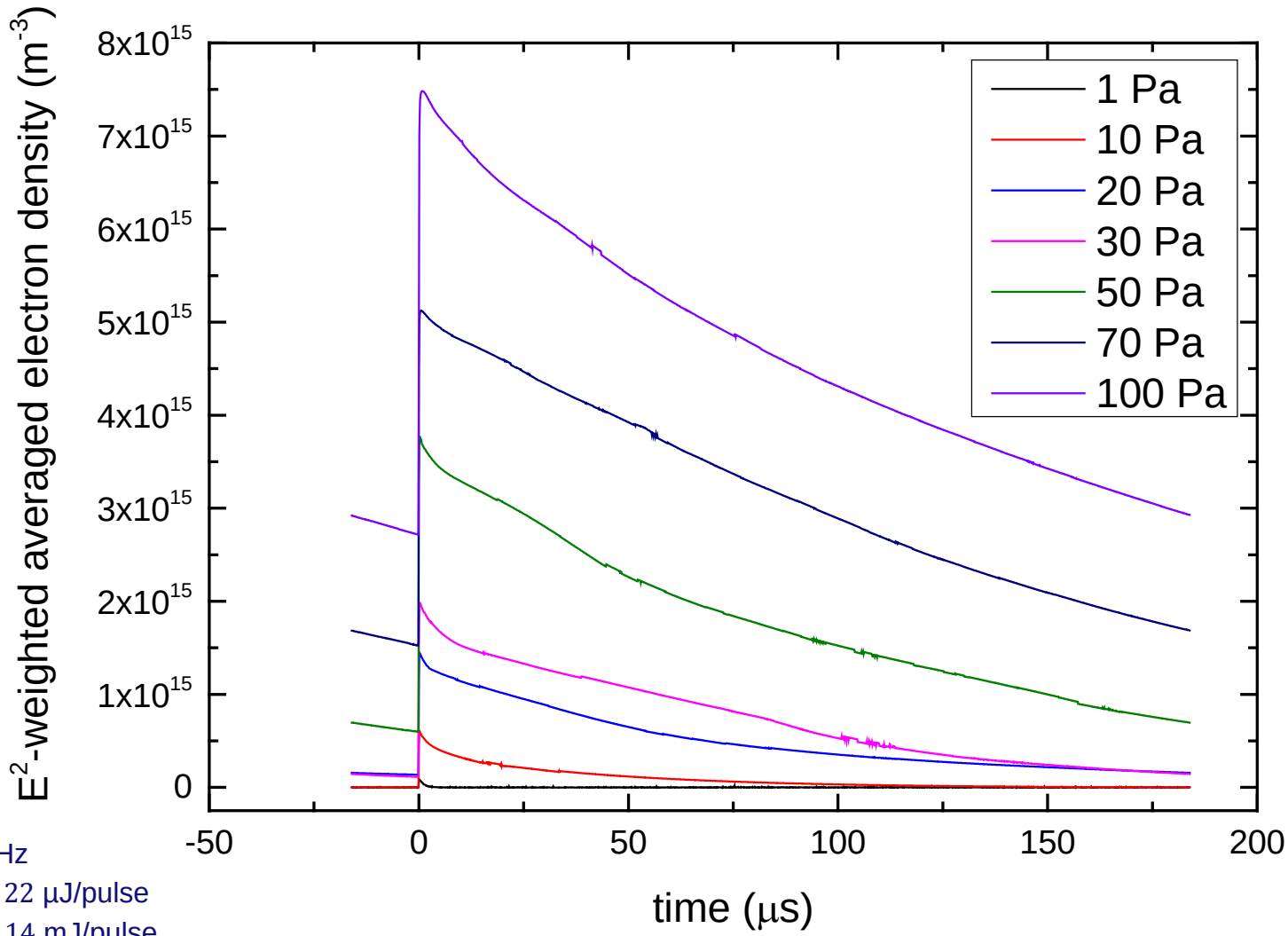
Pressure dependence



$f_{rep} = 5$ kHz
$E_{pulse}^{inband} = 22$ μJ/pulse
$E_{pulse}^{total} = 0.14$ mJ/pulse

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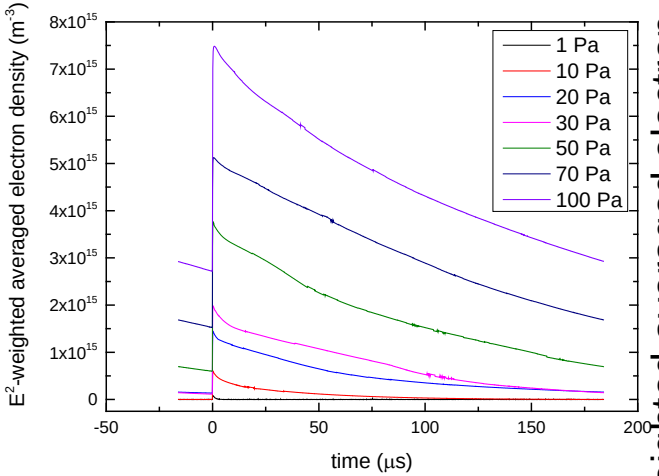

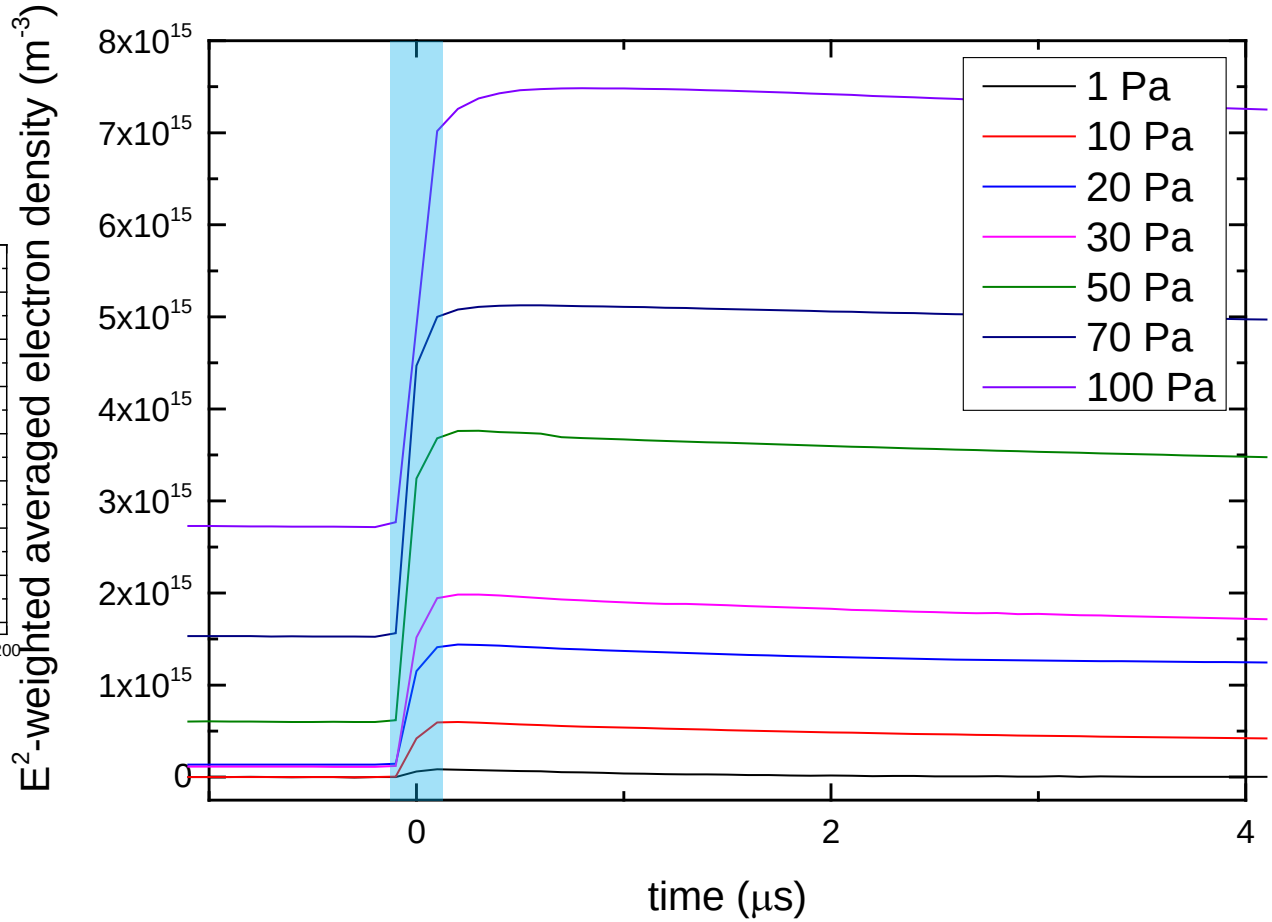

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Peak electron density

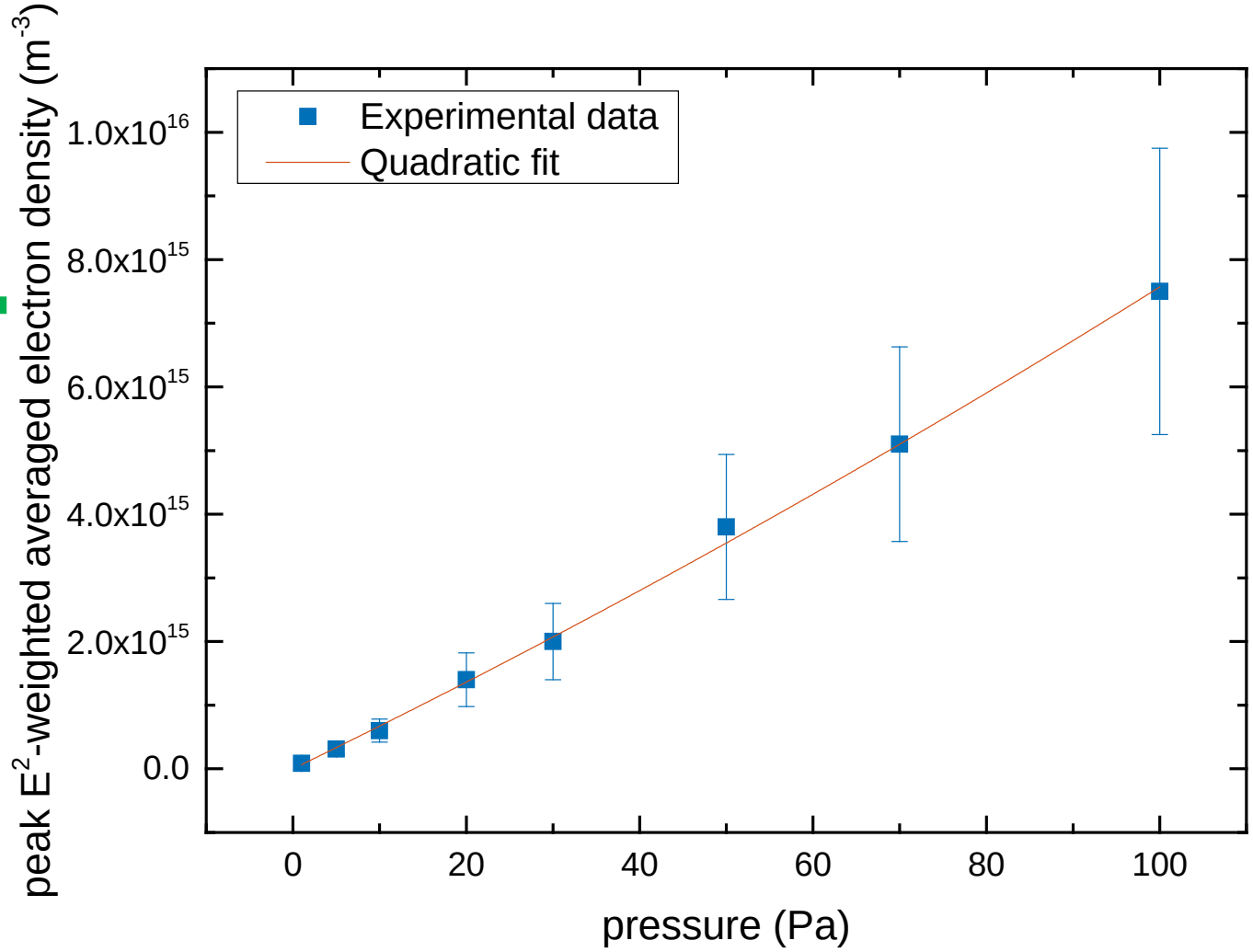
$$\gamma + H_2 \rightarrow H_2^+ + e^-$$

$$e^- + H_2 \rightarrow H_2^+ + e^-$$

$$\frac{dn_e}{dt} = k_{pi} n_a + k_{ei} n_e n_a$$

$$\downarrow$$

$$\alpha n_a$$



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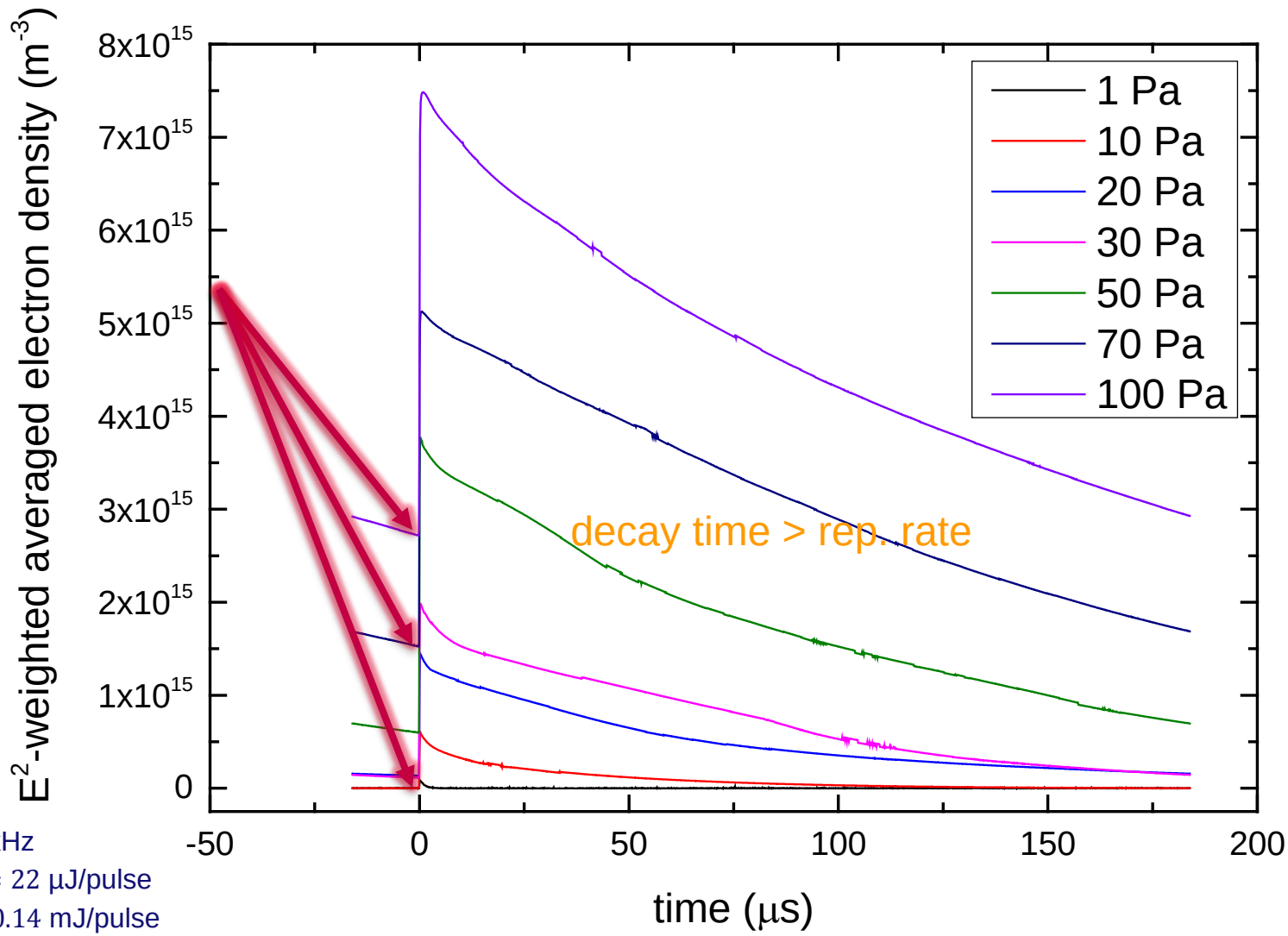
Plasma accumulation



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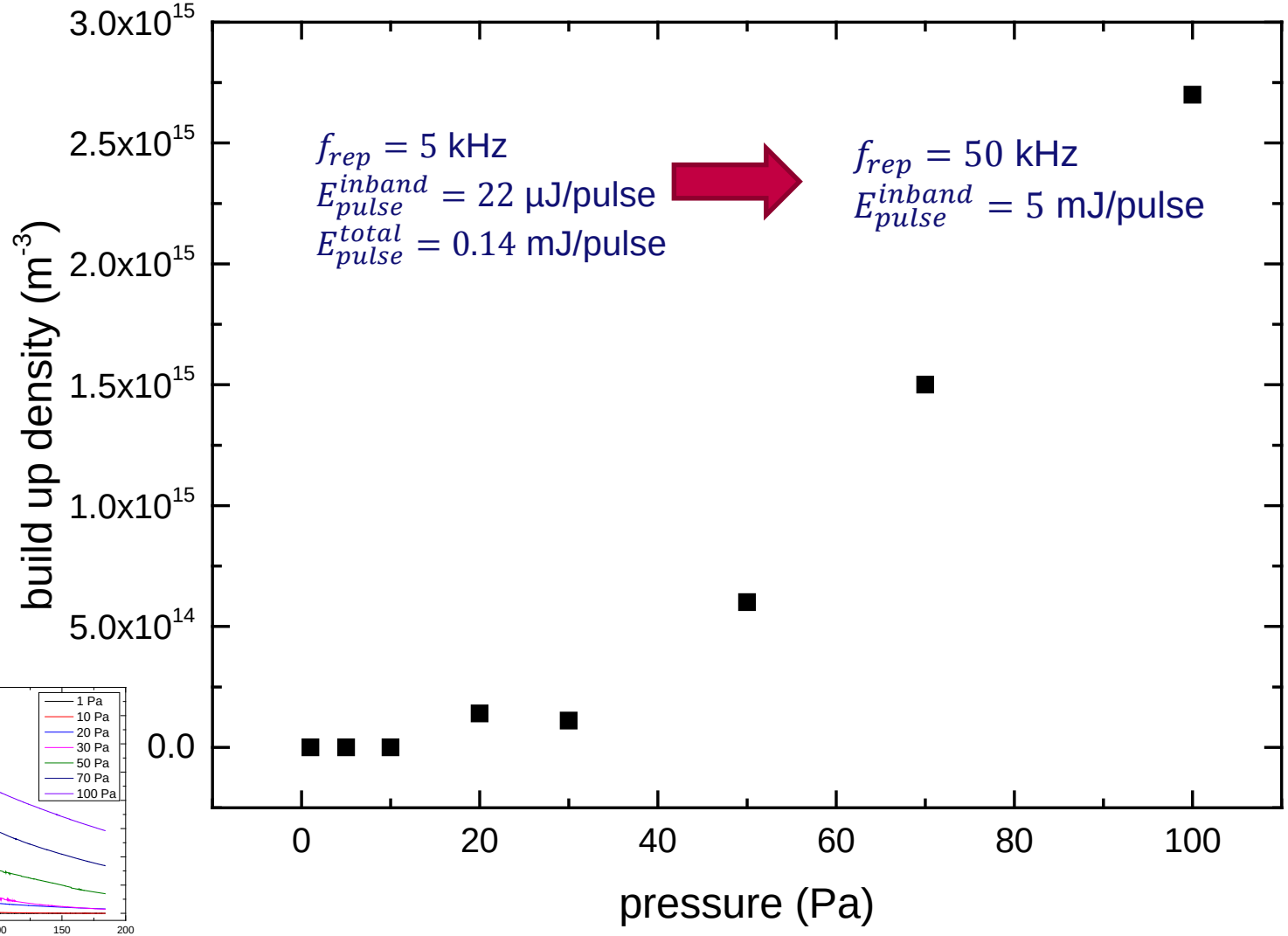

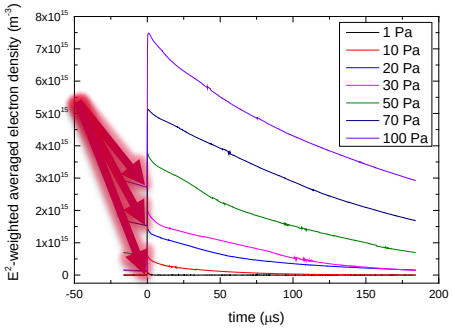

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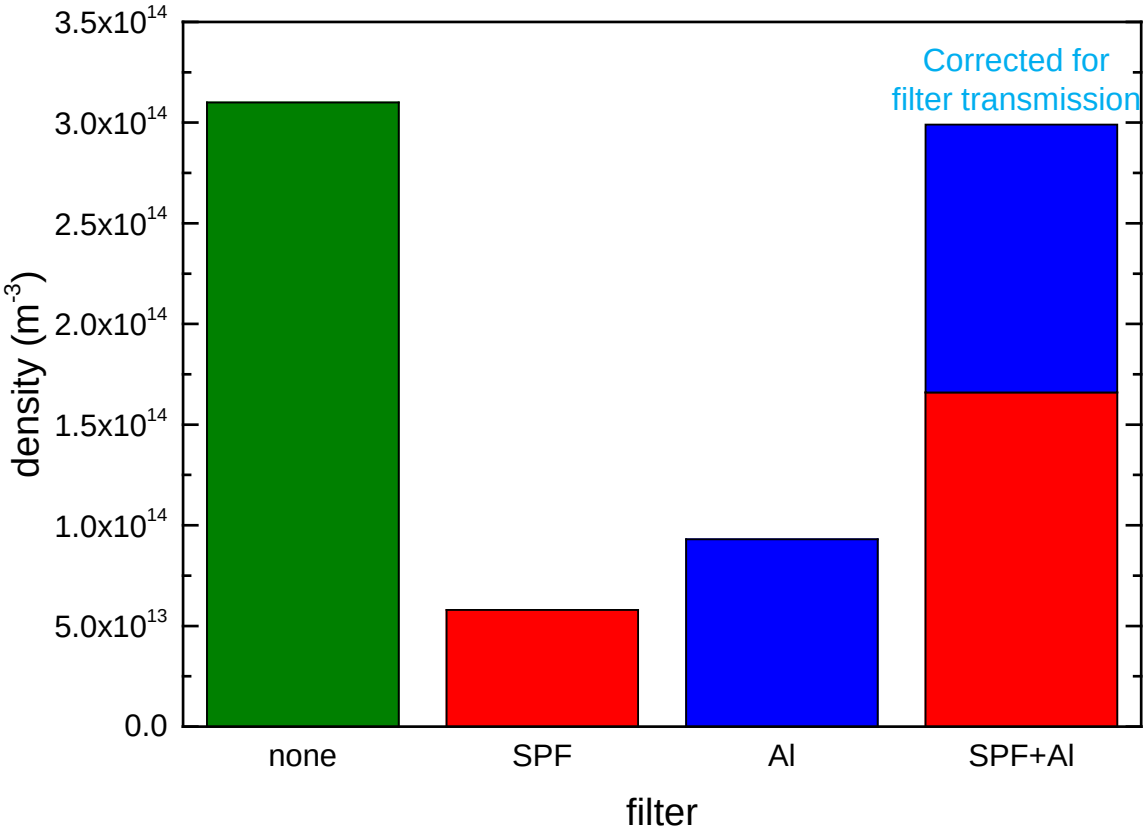
Spectral dependence

- SPF: 10-20nm
- Al: >20 nm



- >20 nm radiation contributes to 50% of plasma generation

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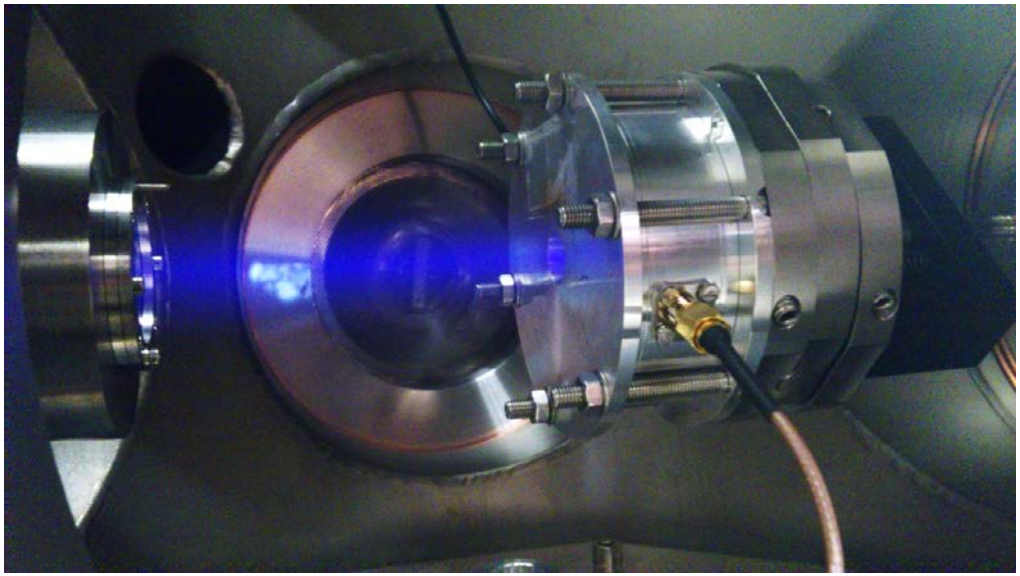
Conclusions

- Pressure dependence
  - Linear contribution of photo-ionization
  - Quadatric contribution of electron impact-ionization
- Accumulation at 20 Pa
- >20 nm radiation important for plasma generation.



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