

## Plasma accumulation effects in Extreme Ultra-Violet generated plasmas

**Citation for published version (APA):**

Horst, van der, R. M., Nijdam, S., Beckers, J., & Kroesen, G. M. W. (2014). *Plasma accumulation effects in Extreme Ultra-Violet generated plasmas*. 1-1. Poster session presented at 26th NNV Symposium on Plasma Physics and Radiation Technology, March 11-12, 2014, Lunteren, The Netherlands, Lunteren, Netherlands.

**Document status and date:**

Published: 01/01/2014

**Document Version:**

Accepted manuscript including changes made at the peer-review stage

**Please check the document version of this publication:**

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

**General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

**Take down policy**

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

# Plasma accumulation effects in Extreme Ultra-Violet generated plasma

R.M. van der Horst, S. Nijdam, J. Beckers and G.M.W. Kroesen



r.m.v.d.horst@tue.nl

## Introduction

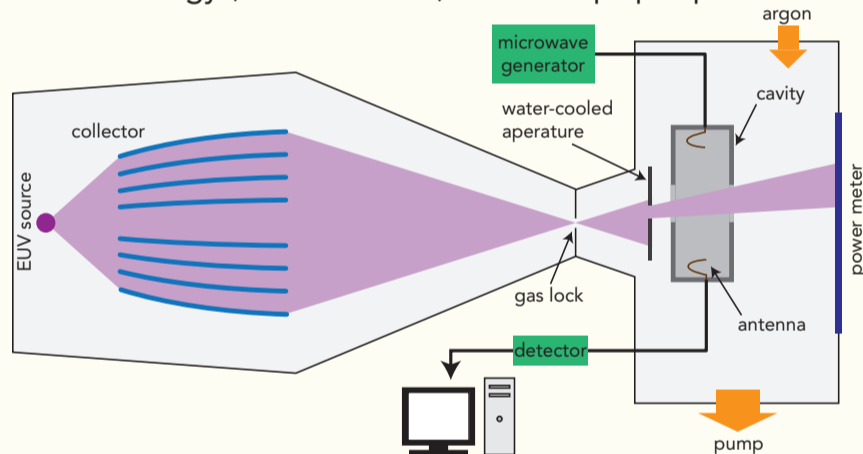
In order to meet the demand of increasing computer speed and memory capacity, industries are striving to reduce the size of computer chips. This miniaturization can be achieved by reducing the wavelength in lithography machines to Extreme Ultra-Violet (EUV, 92 eV). The low-pressure (around 1 Pa) transparent background gas (e.g. H<sub>2</sub> and He) in the lithography machine is partially ionized by the absorption of EUV photons. The study of these low-density (10<sup>15</sup> m<sup>-3</sup>) pulsed plasmas is interesting and experimentally challenging.

### Goal

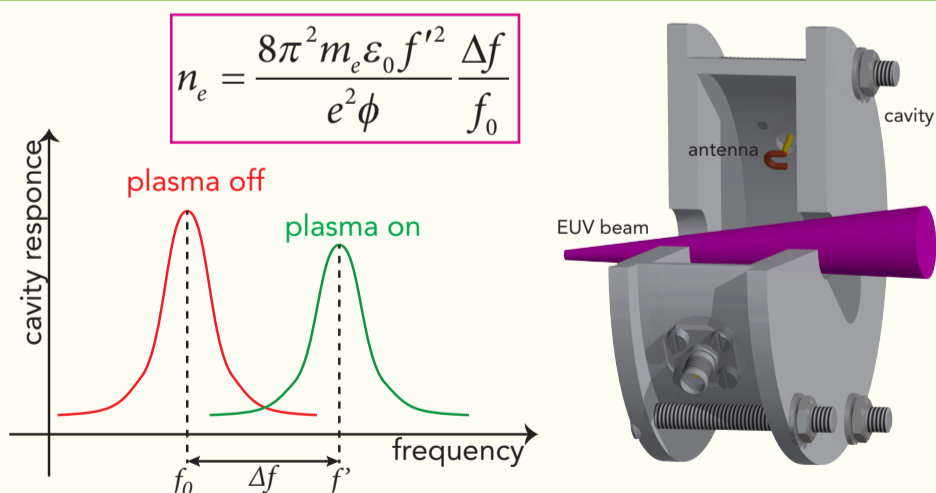
Study the accumulation of electron density in EUV induced plasmas.

## Experimental set-up

- Tin-based LDP source
- Short (sub-μs) EUV pulse
- Frequency:
  - 10 kHz with 50% duty cycle (50 Hz)
  - 500 Hz with 100% duty cycle
- Inband energy (13.5 nm ± 2%) about 12 μJ per pulse



## Microwave cavity resonance spectroscopy

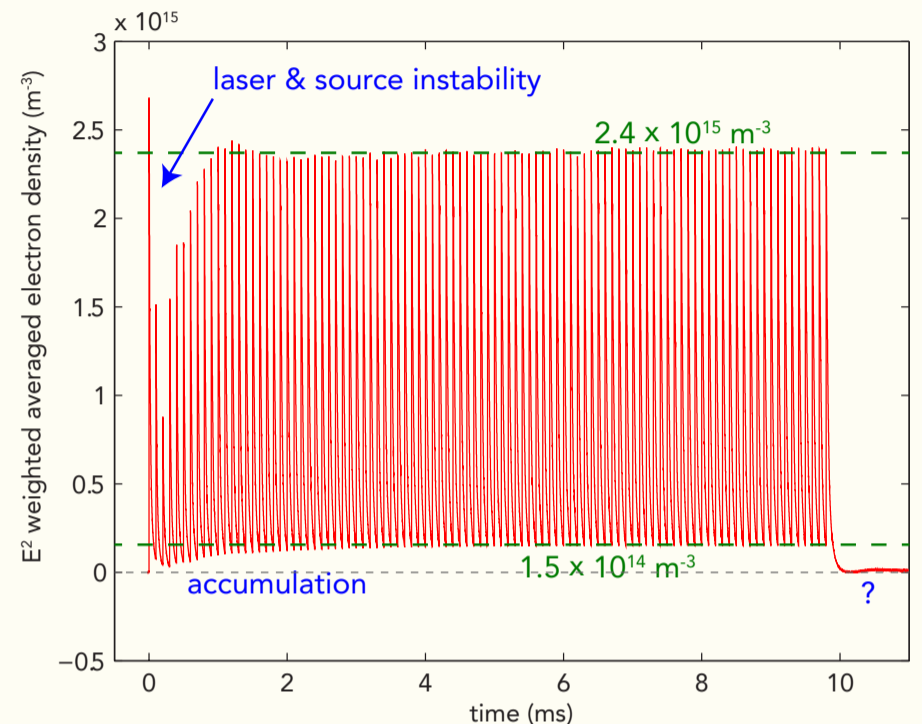


## Conclusions & Outlook

- Plasma accumulation visible at high frequencies
- Accumulation predictable from low frequency measurement
- Repeat experiments in hydrogen
- Perform optical emission spectroscopy experiments

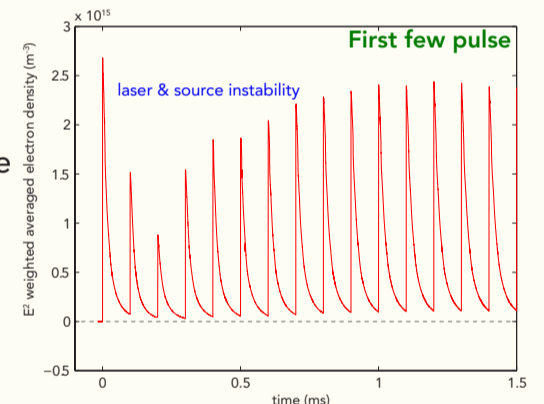
## Plasma accumulation

### 10 kHz measurement



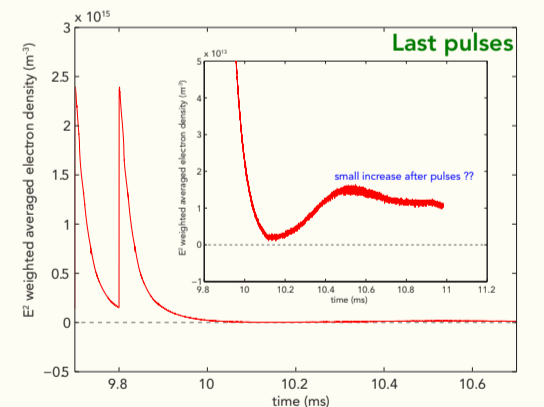
### First pulses

- Laser instability during first pulses
- After 15 pulses steady-state
- Accumulation visible
  - $n_e = 1.5 \times 10^{14} \text{ m}^{-3}$



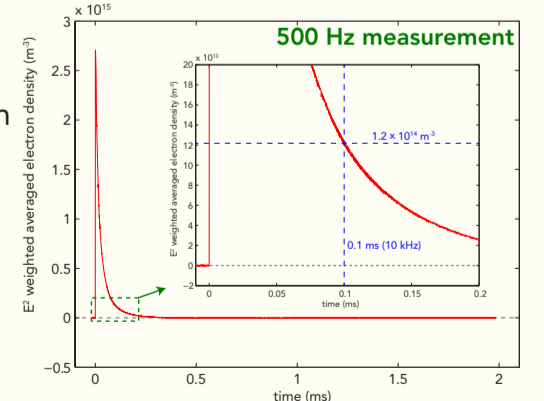
### Last pulses

- Decay in tens of microseconds
- Minimum visible
  - No cavity heating effect
  - Reason yet unknown



### 500 Hz measurement

- Density at 0.1 ms comparable to accumulation at 10 kHz
- Accumulation density predictable



## Acknowledgements

The authors would like to thank the team of ASML Alsdorf for their assistance with the experiments.