SAND2021-10465C

Sandia National Laboratories

DE LA RECHERCHE À L'INDUSTRIE

EXPERIMENTAL STUDIES OF ELECTRON BEAM PROPAGATION IN ARGON

September 1st, 2021

Nicolas Szalek (University of Pau, SIAME)

J. Gardelle, P. Grua, D. Hébert (CEA/CESTA)

C. Moore, B. Medina, M. S. Swan, K. L. Cartwright (SNL)

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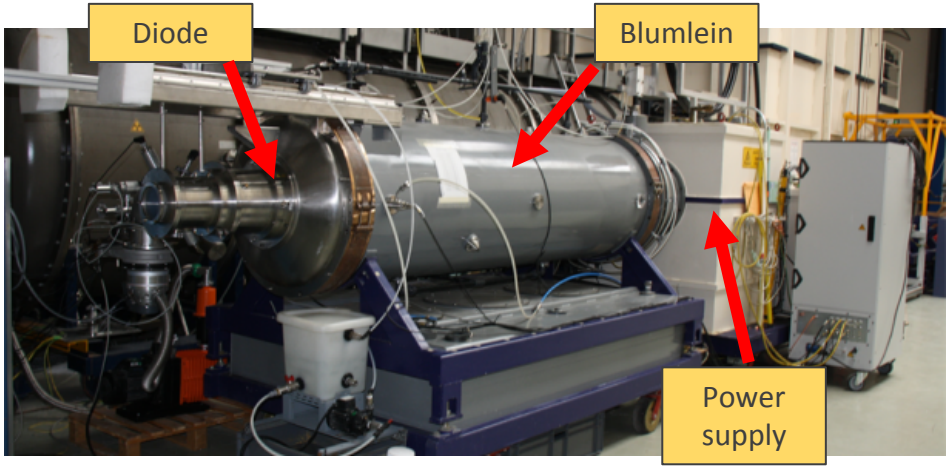
Summary

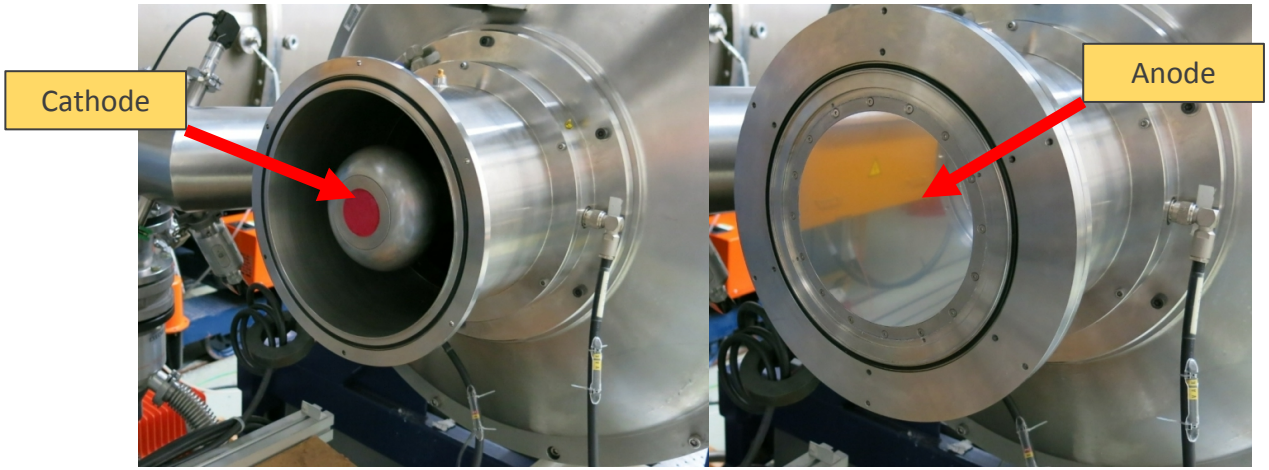
- Experimental setup
- Current measurements
- Beam Imaging
- Plasma light emission
- Comparison with simulations
- Planned experiments
- Conclusion

Joint Presentation : #O8-4
Code-to-code benchmarking of 2D high energy beam transport in a gas cell

Experimental setup

- **Beam parameters**
  - Vacuum diode
  - Velvet cathode
  - Aluminized mylar anode
  - Kinetic energy up to 500 kV
  - Adjustable current 3 < I < 30 kA
- **Beam transport**
  - Gas filled chamber (argon or air)
  - 1e-3 < P <100 mbar
  - 6 return current rods
  - Propagation length: up to 450 mm

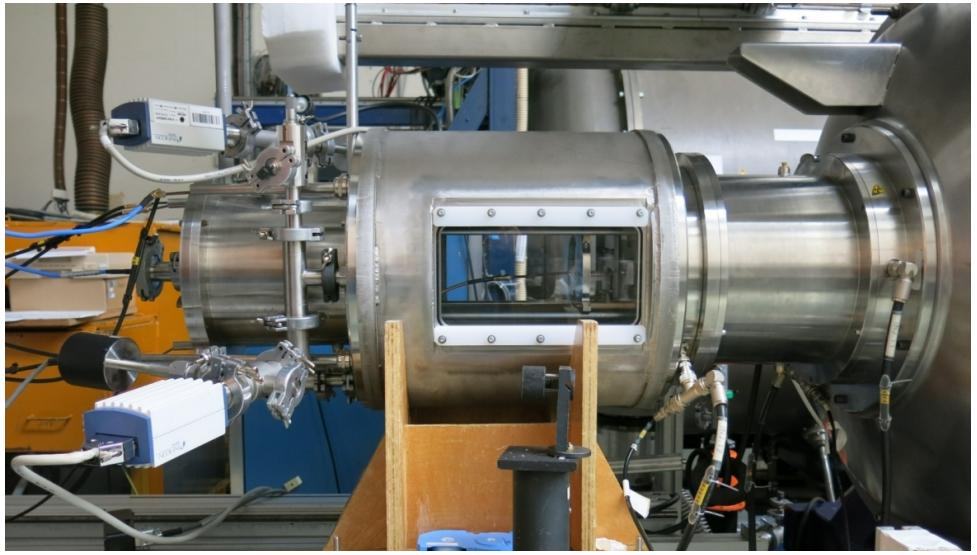




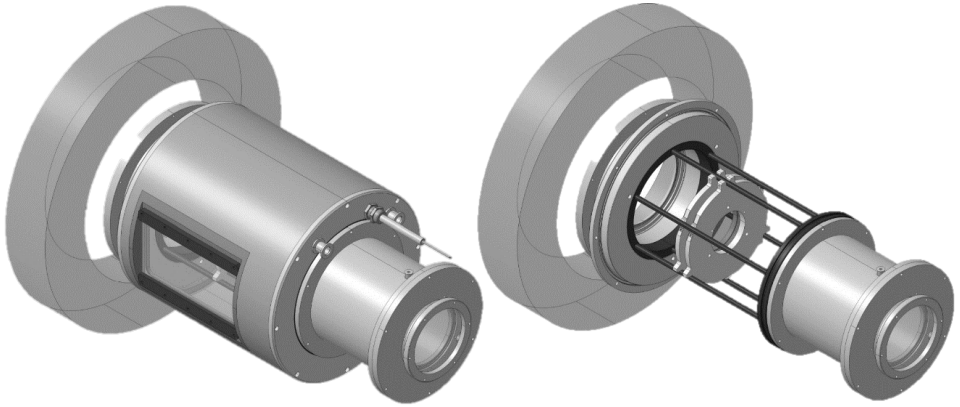
K. Pepitone, J. Gardelle and P. Modin ; JAP 117, 183301 (2015)

Experimental Setup

- **Diode equipment :**
  - Capacitive dividers
  - B-dots
  - Rogowski coil



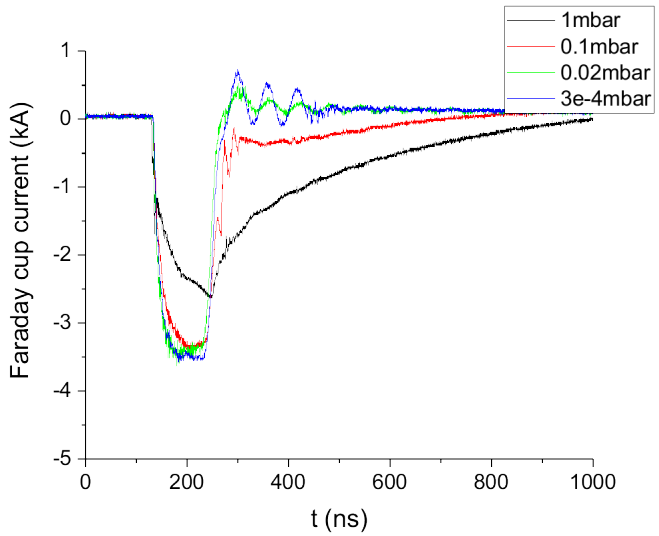
- **Chamber diagnostics**
  - Lateral windows
    - Capture the gas desexcitation light
    - PDV through plasma
  - Movable Bdots and Moebius probes
  - Precise pressure measurements
  - Targets
    - Faraday Cup (beam current measurement)
    - Silica (Cerenkov beam imaging)
    - Aluminum (shocks)
    - Grating (beam axial velocity)



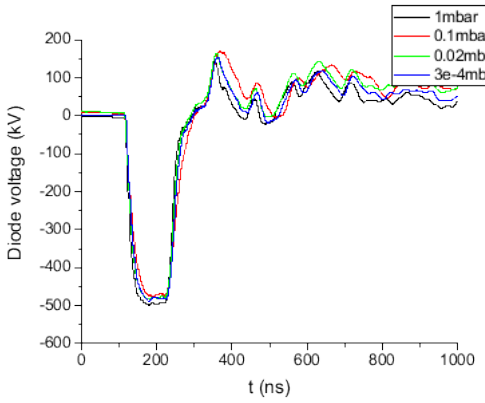
- **Objective : Study of beam/gas interaction, code benchmarking**

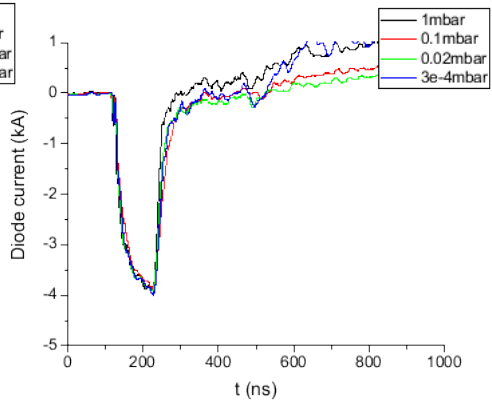
Current measurements

- **Beam current at 100mm: pressure dependance**

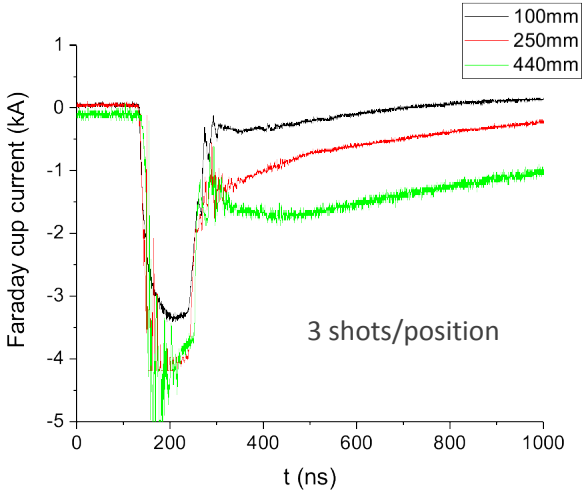


Diode signals

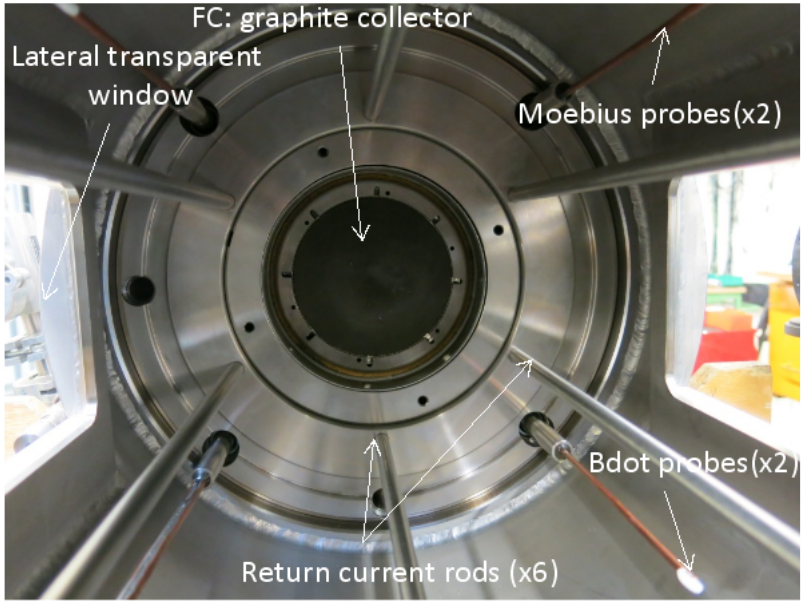




- **Typical beam current at 0.1mbar: transport length dependance**



➔ Simulations in progress



Beam imaging : Cerenkov emission

Setup :

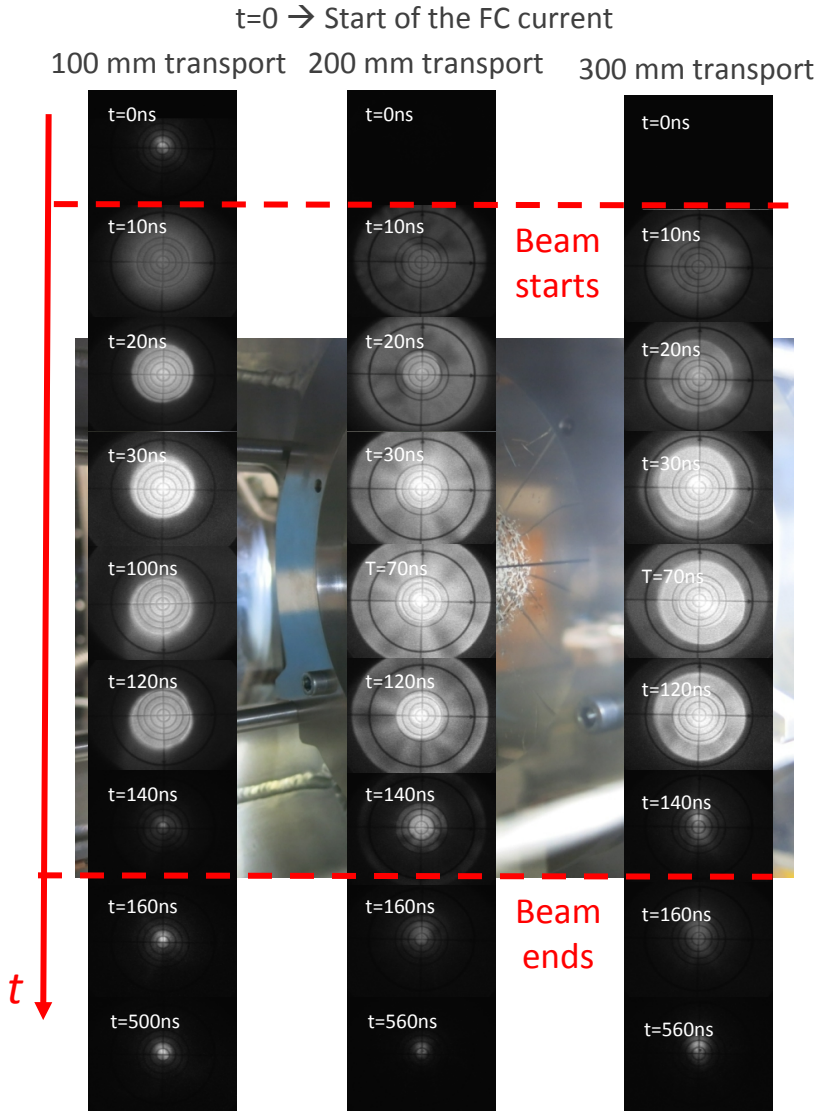
- 2.5mm-thick fused silica target
- Alumized mylar foil on the target
  (electrical grounding)
- 4 images per shot, 3ns exposure

Position dependance :

- At 100mm :
  - Beam diameter : 45mm
  - Beam center : slight corkscrew ?
- At 200mm :
  - Beam halo and « sunrays »
  - Beam core : ~30mm
- At 300mm :
  - Beam diameter : 80mm
  - Beam center : stronger corkscrew
  - Beam halo
  - Less visible and time-dependant beam core

For *t* > 160 ns : Plasma light emission

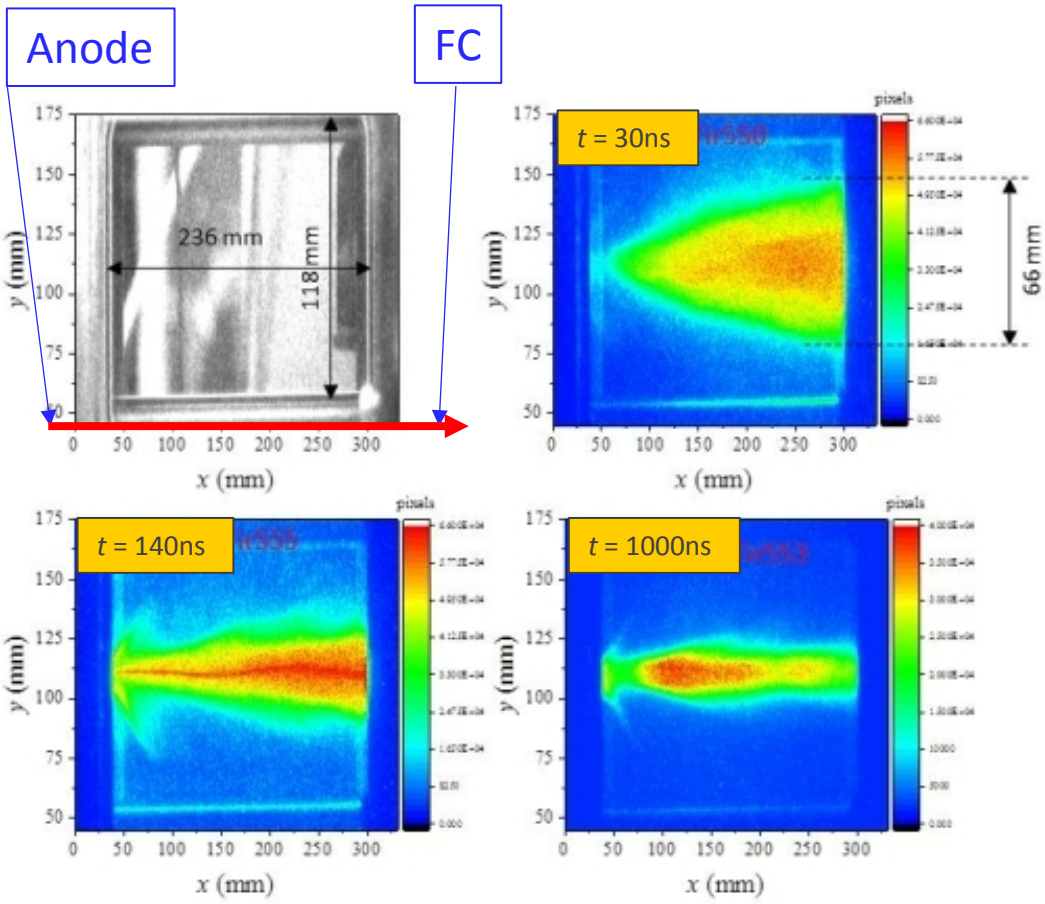
- Visible through the holes in the aluminized mylar foil



→ Rich beam behaviour for simulations

Plasma light emission

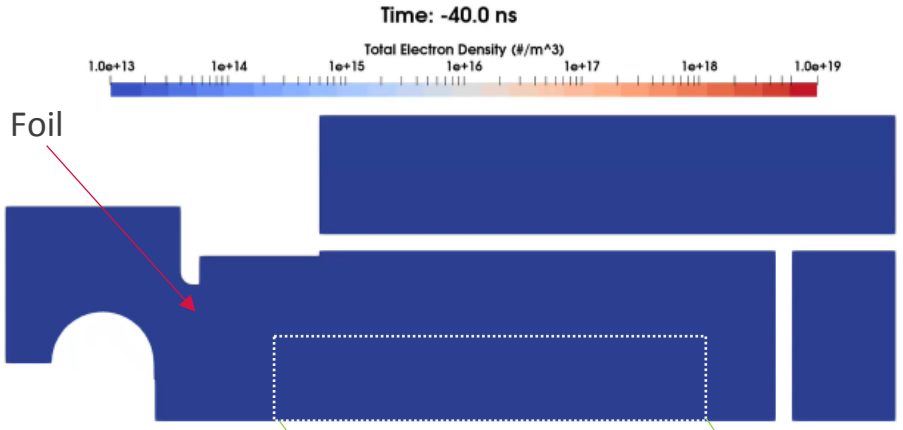
- **Setup :**
  - FC at 400mm
  - Light capture through the lateral window
  - 4 images per shot, 10ns exposure
- **First times :**
  - Beam has already pinched down and focused early in the pulse
  - The ionization seems to start at long distances
- **During the beam plateau :**
  - Beam seems to be focused in the first 50mm of the gas cell
  - A moving small-diameter plasma channel appears after the beam focus point
- **At long times:**
  - The secondary plasma persists long after the beam (over 1µs)
  - Structure from the beam is still seen



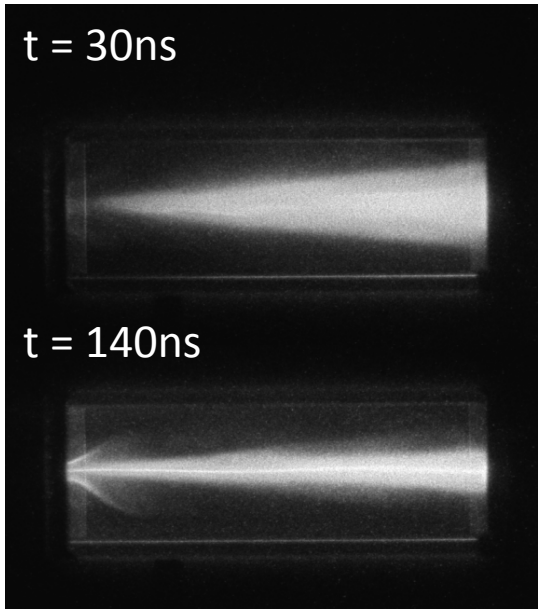
Comparison with simulations: Side view

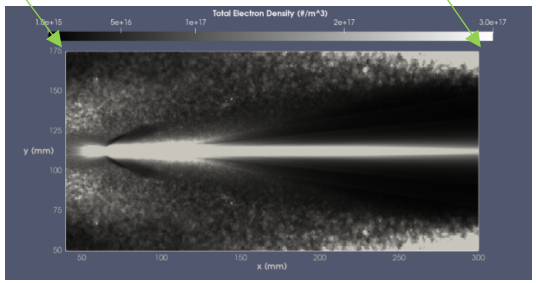
- The current experiments with RKA are used to benchmark simulation codes such as EMPIRE (SNL) and GAZEL (CEA/CESTA)

- Side view



Observed light emission from excited states





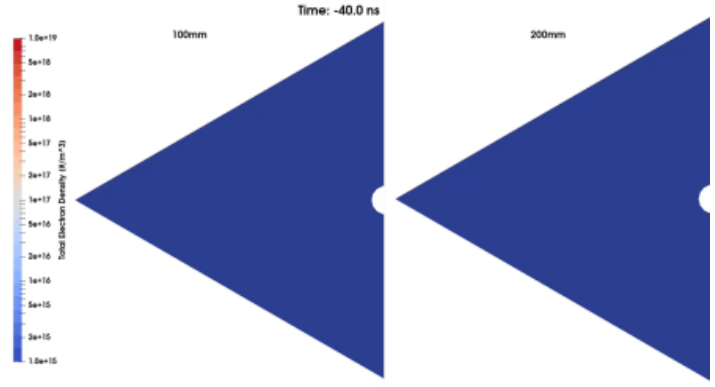
Simulated electron density (linear scale) averaged from 20 to 30ns

Future efforts:

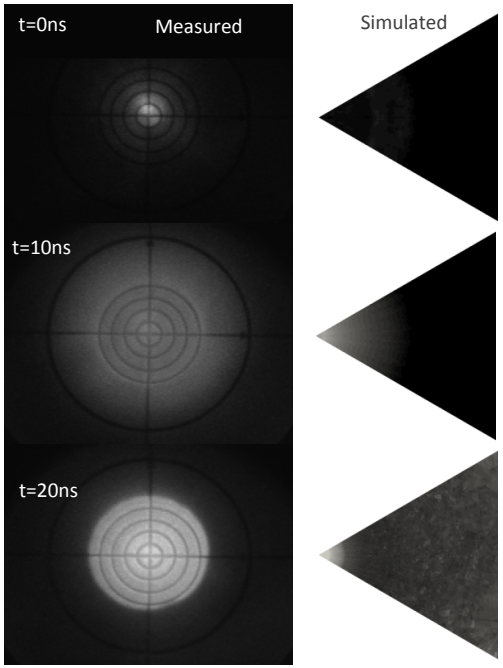
- Simulate to longer times
- Track excited states
- Simulate the observed spontaneous emission spectra

Comparison with simulations: Beam Profile

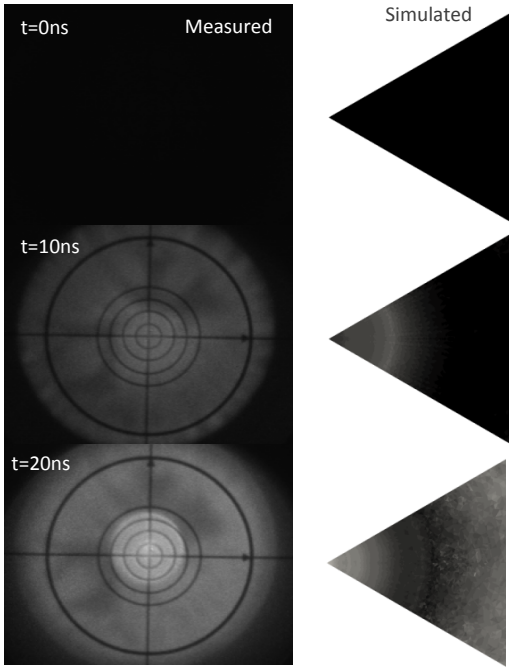
- The current experiments with RKA are used to benchmark simulation codes such as EMPIRE (SNL) and GAZEL (CEA/CESTA)



100 mm beam profile



200 mm beam profile

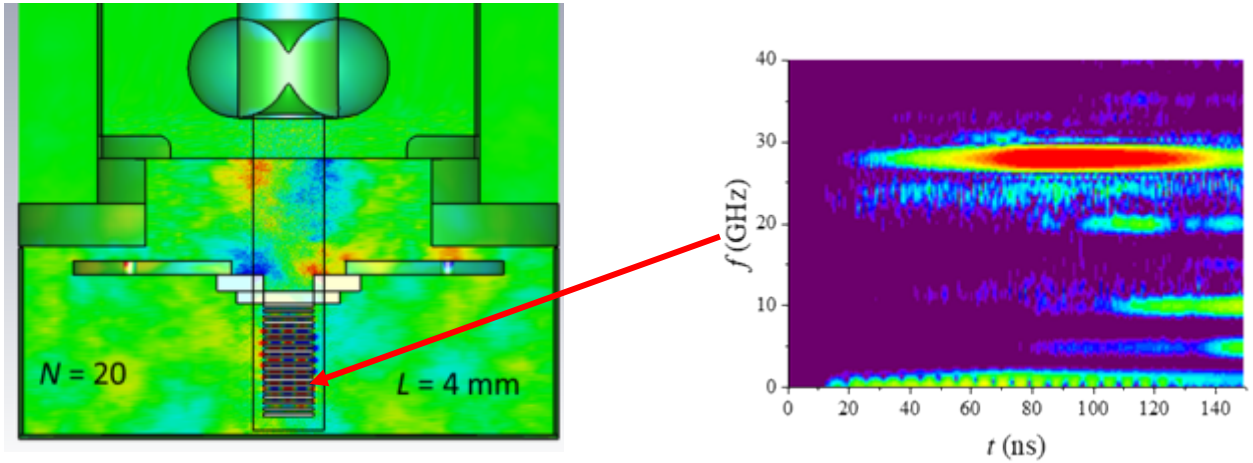


Planned experiments

Beam axial velocity measurement

- Interaction between the beam and a lamellar grating [1]
- The frequency of the interaction depends on the electron kinetic energy and the 3D grating modes

CST simulation, RKA Diode



Plasma electron density measurement

- PDV measurement through lateral windows [2]
  - The plasma changes the optical path of the beam. We measure a « velocity » that can relate to the density

$$v^*(t) \approx -L\frac{d\hat{n}}{dt} \qquad n = \sqrt{1 - \frac{N}{N_c}}, \quad N_c = \frac{m_e \epsilon_0}{e^2}\left(\frac{2\pi c}{\lambda}\right)^2$$

- Microwave interferometer

[1] *J. Gardelle, P. Modin and J. T. Donohue, IEEE Transaction on THz science and technology 7, 151 (2017)*

[2] D.H.Dolan, K. Bell, JAP 123, 034502 (2018)

Conclusion

RKA experimental setup has been improved

- Dedicated RKA propagation chamber in the framework of CESTA/SNL basic science collaboration
- New and many diagnostics
- High RKA reliability and good beam reproducibility

First experimental results :

- Beam current shapes and spatial transverse profiles strongly vary with distance and *Ar* pressure
- Plasma emission lasts long times

→ **Useful to start fine EMPIRE and GAZEL benchmarking**

First comparisons between simulations and experiments

- Qualitatively similiar beam pinching and profiles
- Implementing emission diagnostic in order to compare simulated emission spectra/intensity with observations
- Future comparisons will better match the simulated upstream pulse conditions to measured pulse

Experimental work is going forward with:

- Improved diagnostics (voltage, current, axial velocity, plasma density,…)
- Increased statistics for different setups
- Better choice of measurements to compare with simulations
- Similar experiments are planned at SNL with the SPHINX facility