Laser triggered Z-pinch EUV source

Isaac Tobin[1]*, Larissa Juschkin[2,3], Vasily S. Zakharov[4], Sergey V. Zakharov[4], Yuri Sidelnikov[5], Fergal O'Reilly[2], Paul Sheridan[2,6], Emma Sokel[2] and James G. Lunney[1]

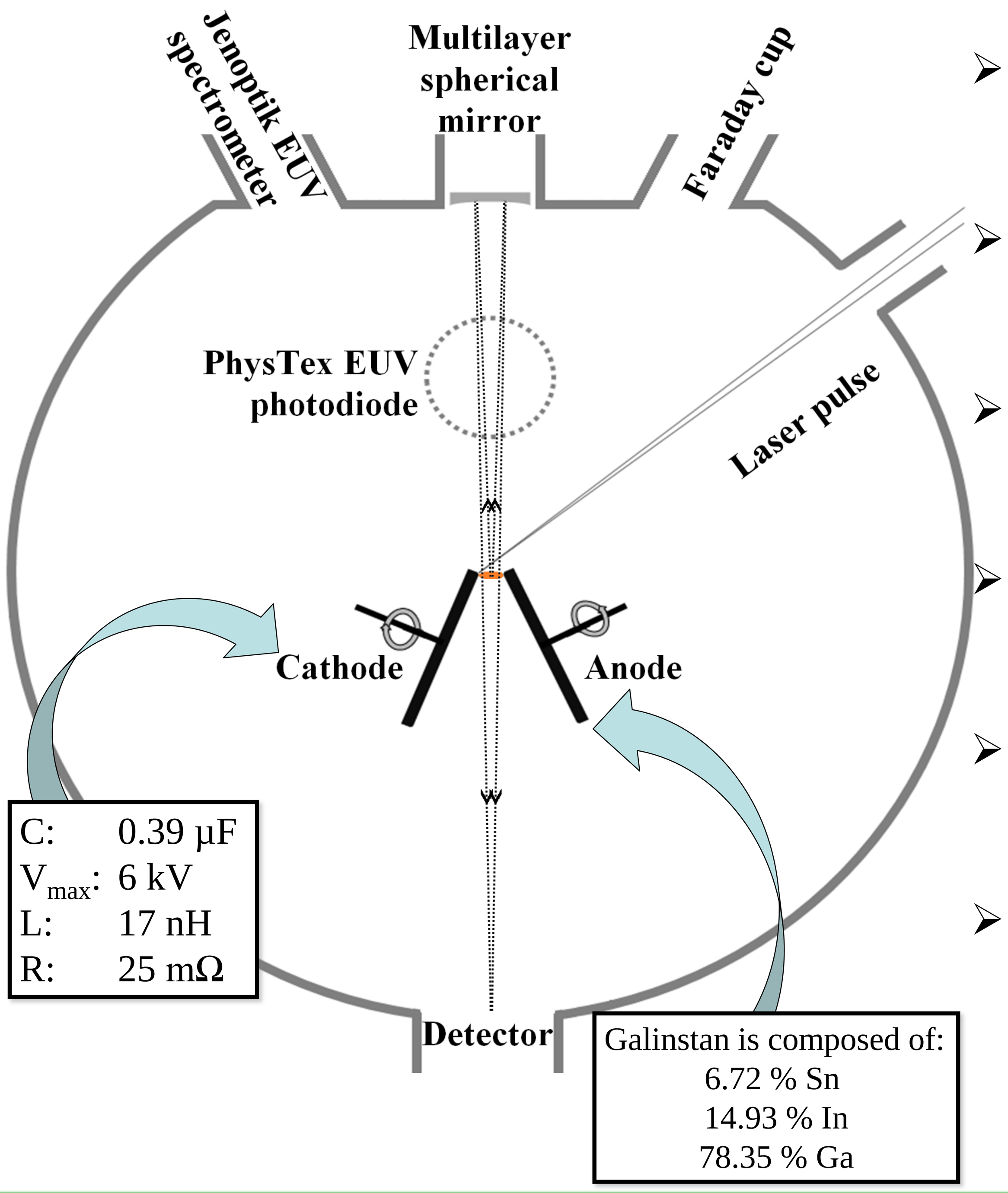
[1]School of Physics, Trinity College Dublin, Ireland, [2]School of Physics, University College Dublin, Ireland,
[3]Department of Physics, RWTH Aachen University, Germany, [4]EPPRA sas, Villebon sur Yvette, France,
[5]ISAN Institute of Spectroscopy, Troitsk, Russia, [6]Newlambda Technologies, UCD Science Centre North, Ireland.

*tobindi@tcd.ie

Current prototype EUV sources for lithography utilise tin as a source material. Galinstan (Ga-In-Sn) as a fuel material in this type of source is novel as it is liquid at room temperature. In this the EUV emission characteristics of galinstan and Sn are compared for the similar source parameters. In the LAVA-lamp source a high-current discharge is triggered by laser ablation of the liquid metal film on one of the rotating electrodes.

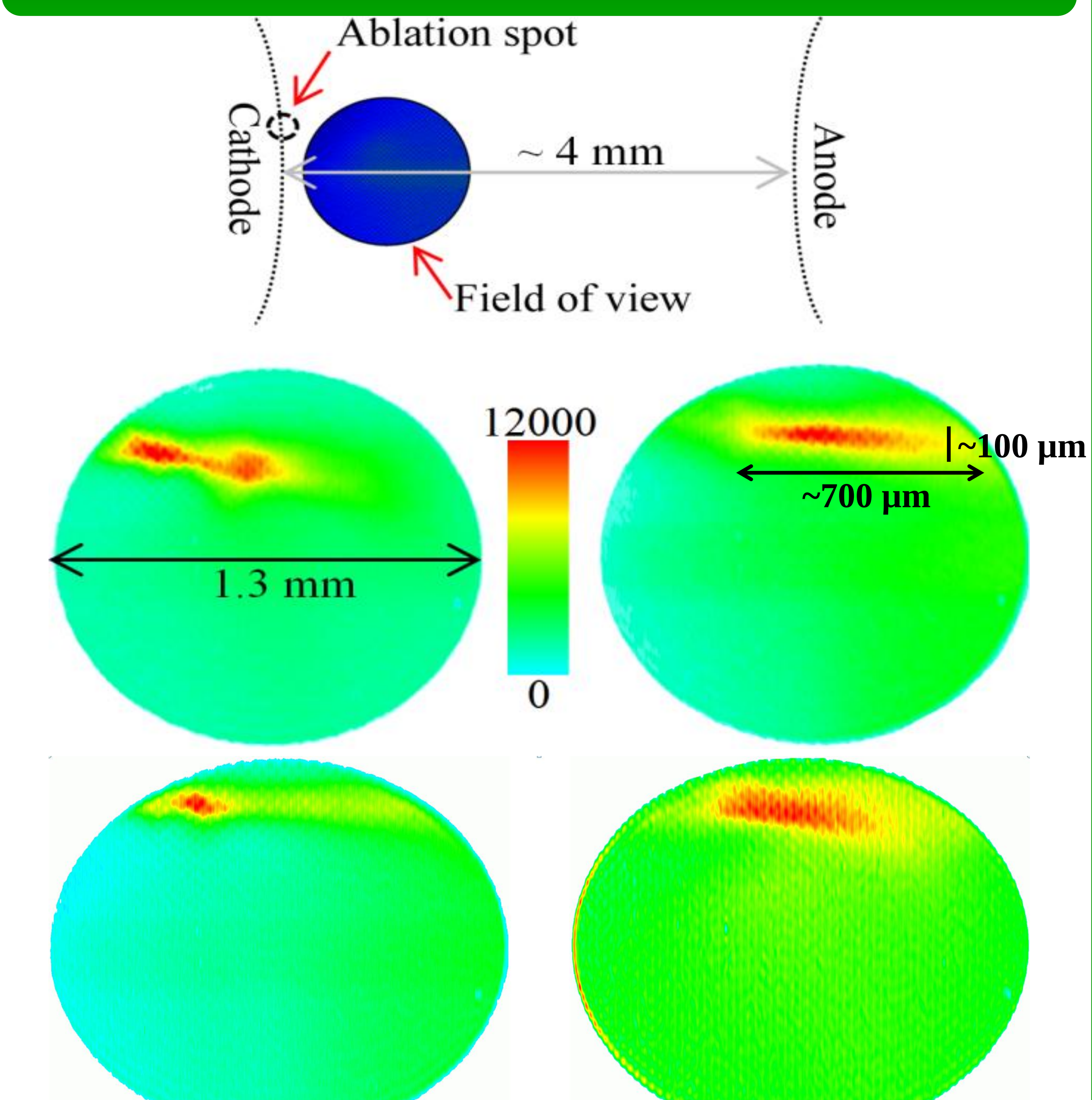
The results have so far shown that in-band EUV emission at 13.5 nm from Sn is more reproducible and between 1.5x and 10x higher than from galinstan. The low percentage of Sn (6.72%) and strong out-of-band EUV emission from Ga and In ions could be the cause of the lower in-band efficiency. The source parameters were also optimised only for Sn and not for galinstan which should yield improvement as indicated by results at lower discharge energies. The energy conversion efficiency (CE) into 2π sr in a 2% band at 13.5 nm is 0.22 % for tin and 0.089 % for galinstan. Relative to tin the CE for galinstan is higher than expected according to the percentage of tin, which may be partly due to the influence of optical opacity in the tin discharge.

Experimental setup



- **Jenoptik absolutely calibrated time integrated EUV spectrometer,**
- **2 µm spatially-resolved time-integrated in-band EUV imaging of the pinch,**
- **Phystex in-band EUV filtered detecting photodiode,**
- **Rogowski coil characterisation of discharge current,**
- **time- and spatially-resolved fast gated visible emission spectroscopy,**
- **time of flight diagnostic of ions with a Faraday cup**

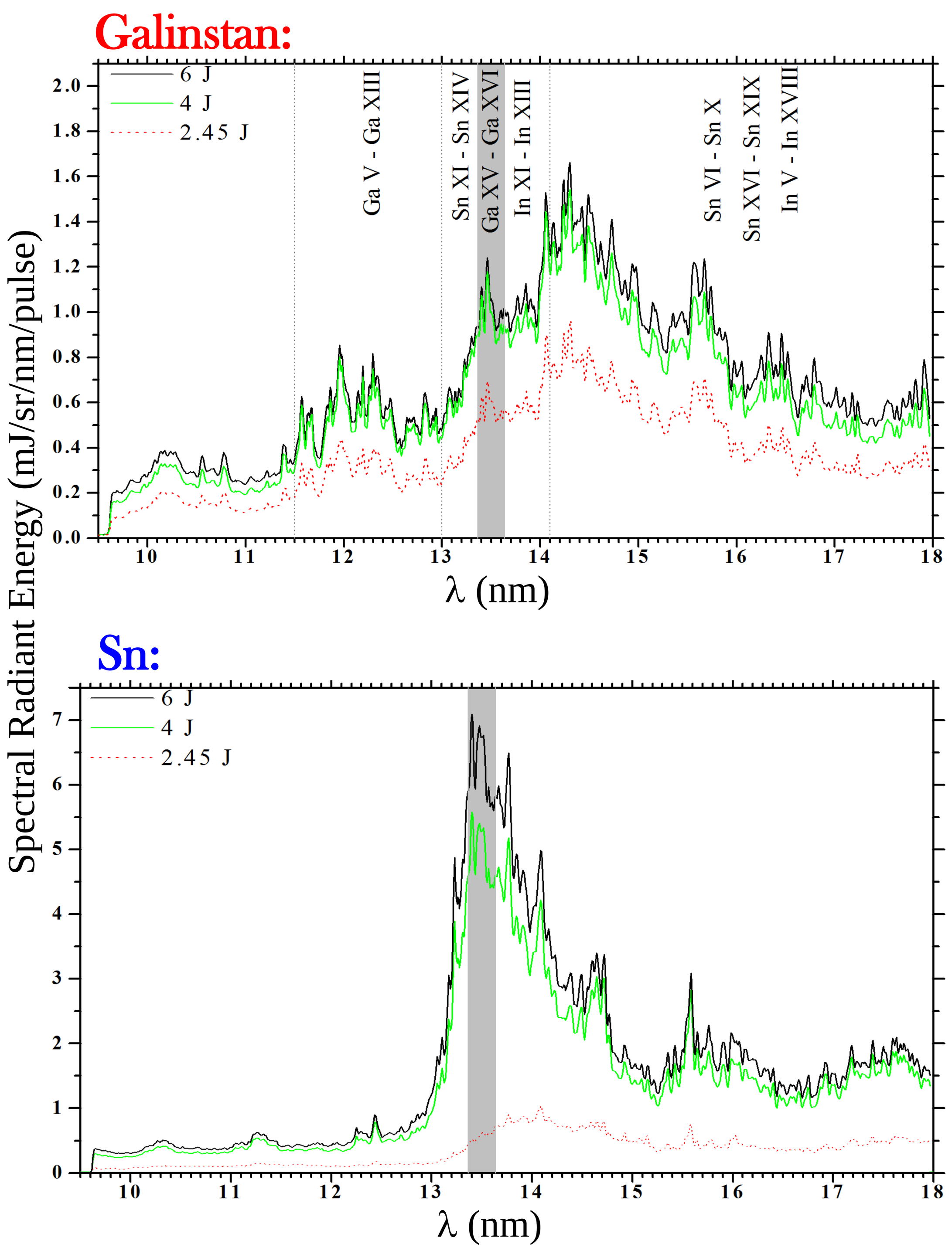
EUV imaging of galinstan pinch region



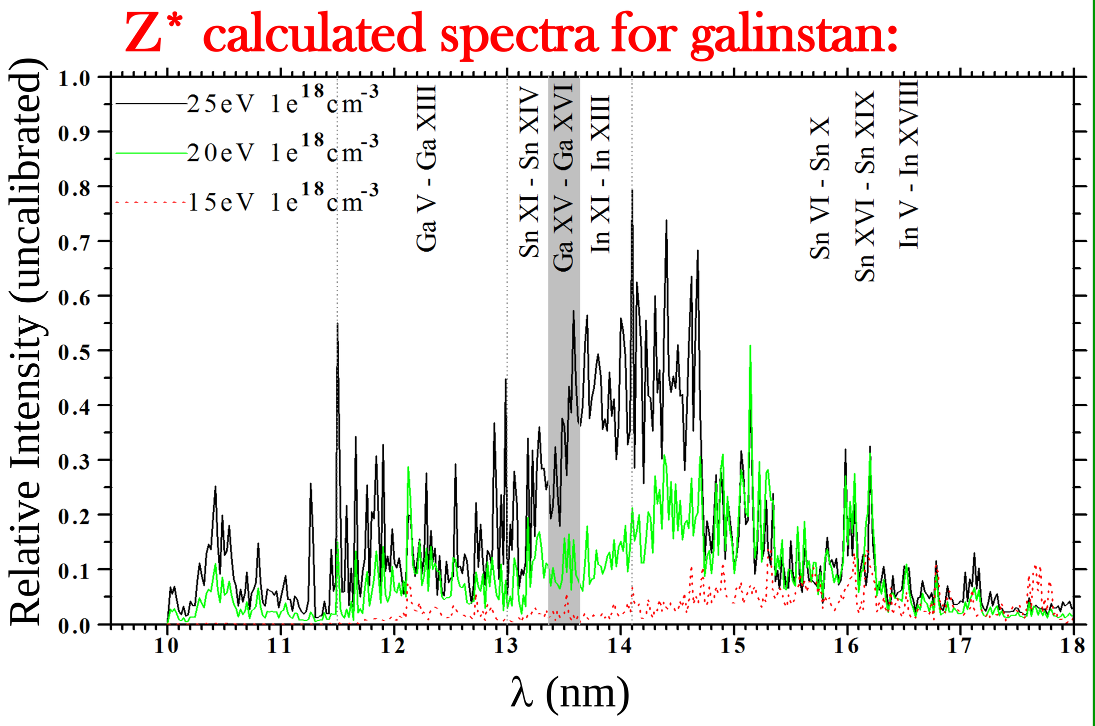
4.05 J discharge triggered with a 5 mJ 30 ns laser pulse.

Further analysis

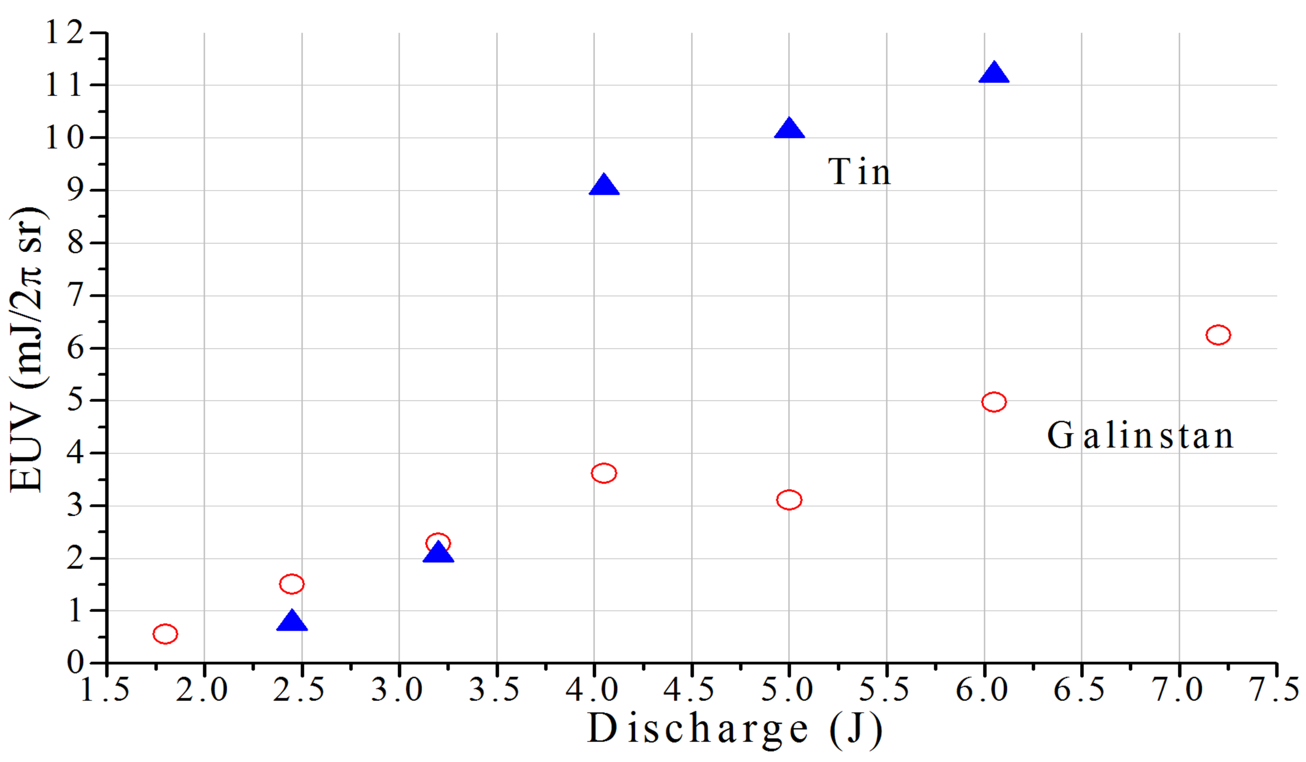
- **Jenoptik EUV spectra for various discharge energies:**



Z* calculated spectra for galinstan:



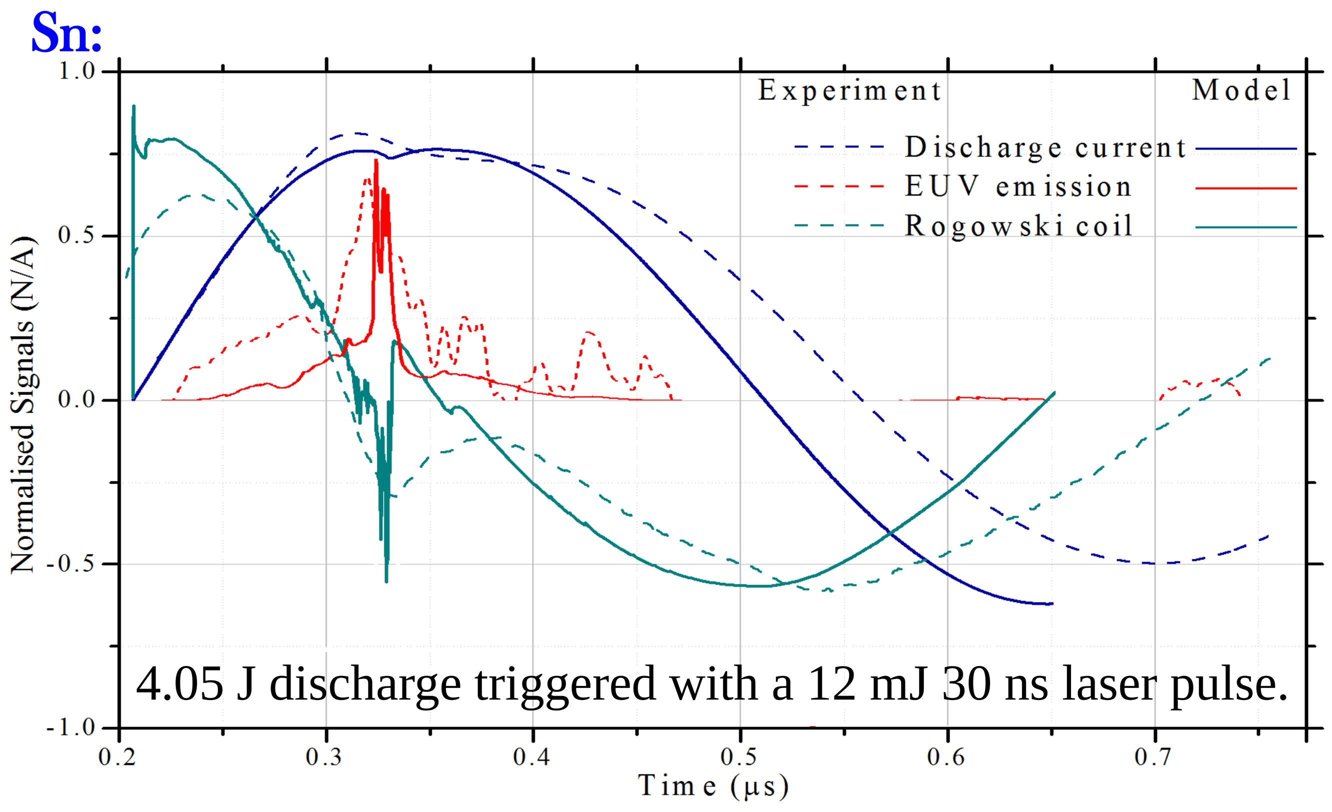
- **Inband EUV emission from Phystex detector:**



- Increased in-band emission for both materials with increasing discharge energy.
- Conversion efficiency into 2π sr for a 4 J discharge is 0.22 % for tin and 0.09 % for galinstan.
- In-band emission measured by PhysTex photodiode agrees well with Jenoptik spectrometer results.

- **Comparison of experimental and Z* calculated tin discharge current and in-band EUV emission:**

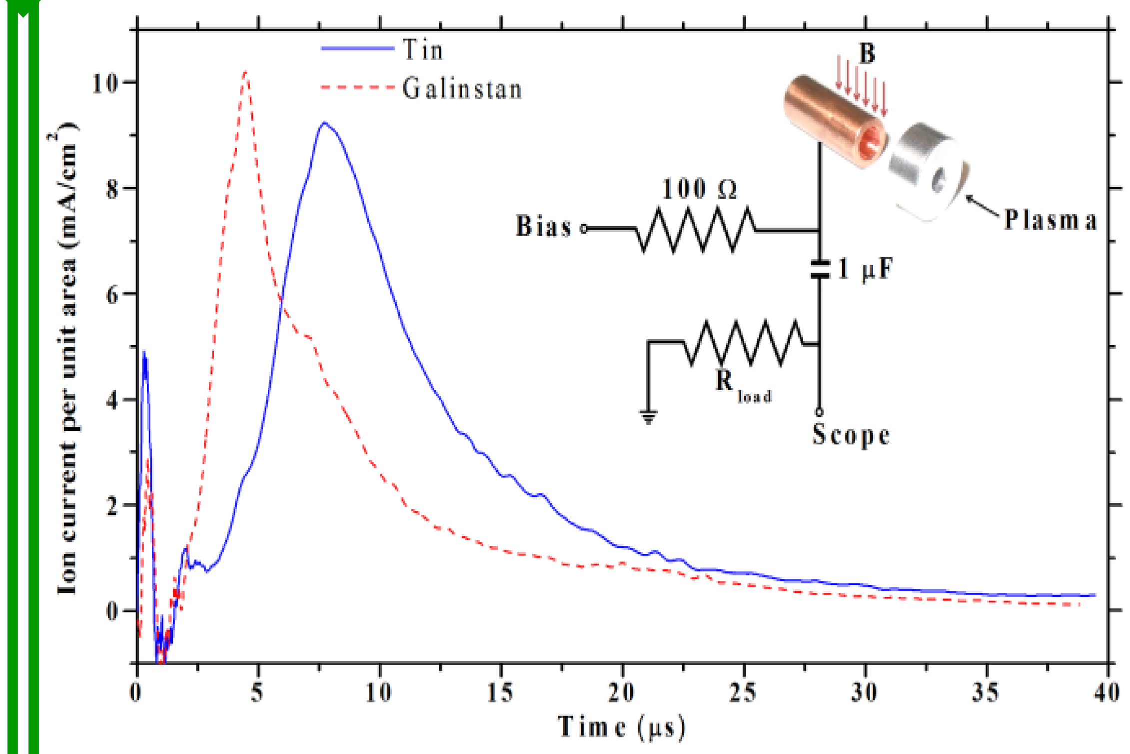
Sn:



4.05 J discharge triggered with a 12 mJ 30 ns laser pulse.

N.B. The experimentally recorded EUV emission is for the band 6 nm – 18 nm as emission was recorded using a 0.5 µm Zr filter in front of an IRD fast photodiode (AXUVHS5).

- **Faraday cup ion time of flight signal:**



Conclusions:

We have compared the performance of galinstan and Sn in a laser triggered discharge source

- Galinstan is useful source material as avoids the complication of keeping Sn molten.
- So far we have observed EUV emission from Sn to be more efficient by a factor of between 1.5x and 10x.

→ lower EUV emission could be caused by low percentage of Sn or strong out-of-band EUV emission from Ga and In ions.

- Matching the pinching time to the maximum current is essential for high EUV output and is sensitive to trigger laser energy.
- EUV imaging – pinch is ~ 100 µm in diameter and ~ 0.5 mm – 1 mm in length.

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