

# The Oxford Plasma Accelerator Laboratory (OPAL)

David McMahon, Linus Feder, James Chappell, James Cowley, Emily Archer, Darren Z. Chan, Sebastian Kaloš, Wei-Ting Wang, Johannes van de Wetering, Roman Walczak, Simon Hooker

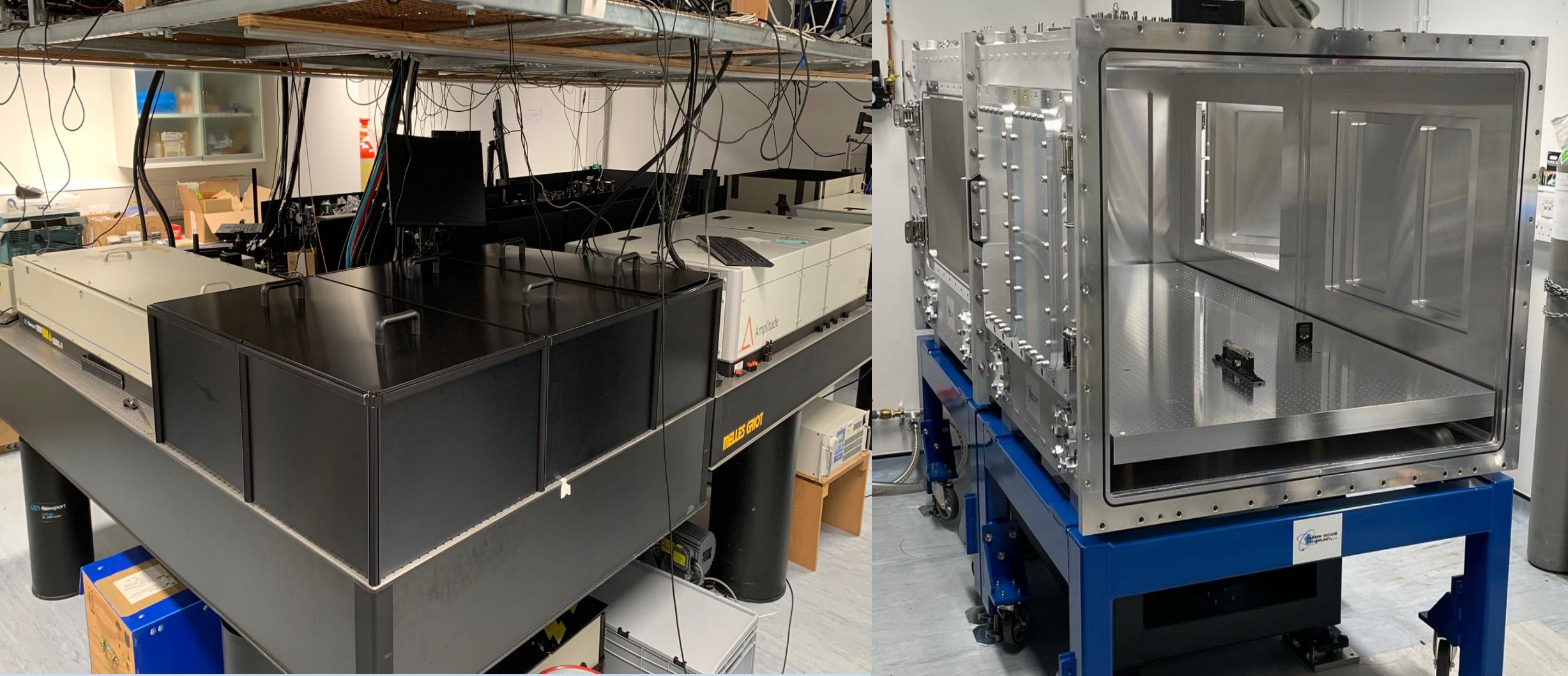


John Adams Institute for Accelerator Science and Department of Physics, University of Oxford, Denys Wilkinson Building, Keble Road, Oxford OX1 3RH, UK



## Introduction

The Oxford Plasma Accelerator Laboratory (OPAL) is a dedicated facility to study channel-guided laser wakefield acceleration (LWFA) with high-resolution high-volume statistics. The facility houses a dedicated 80 m<sup>2</sup> laser area adjacent to 2 target areas (40 m<sup>2</sup> and 46 m<sup>2</sup> in area.)

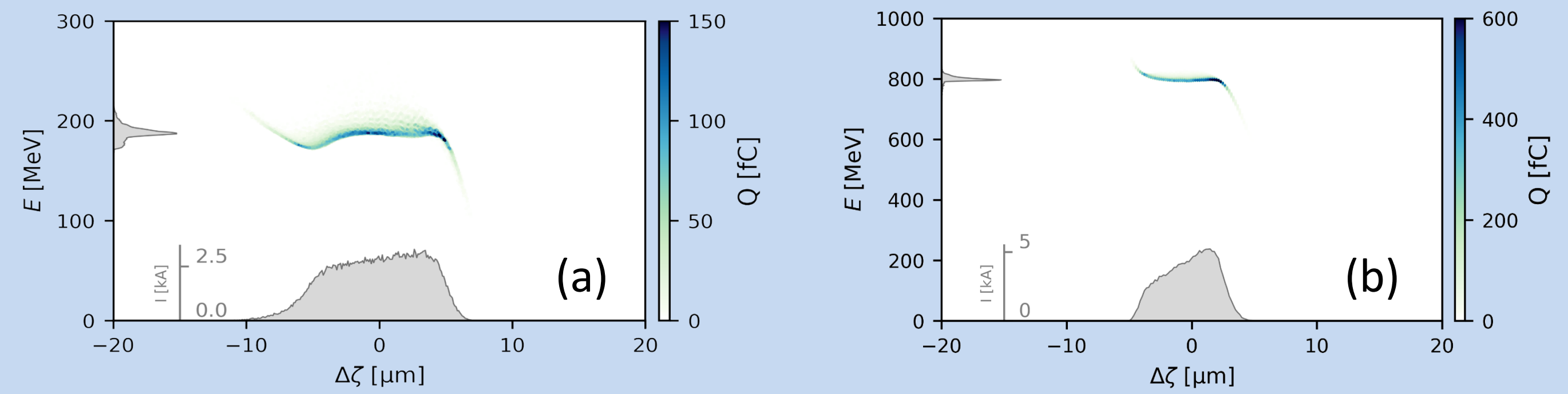


Laser area containing kHz beamline and main beam amplifiers.

Dedicated 2.5 m x 1.3 m x 1 m vacuum chamber in Target Area 2 for LWFA experiments.

## Facility Capabilities

- OPAL is equipped with a kHz beam (1 kHz, 50 fs, 2.5 mJ) and a main beam.
- Main beam (10 Hz, 45 fs, 0.6 J) is energetic enough to form CHOFI channels and accelerate 100 pC charge, 200 MeV average energy, electron bunches.
- Jan '24 upgrade to (10 Hz, 35 fs, 1 J) includes 100 mJ compressor, enabling independent compression of 2 beamlines, and 100 pC, 800 MeV, bunches.

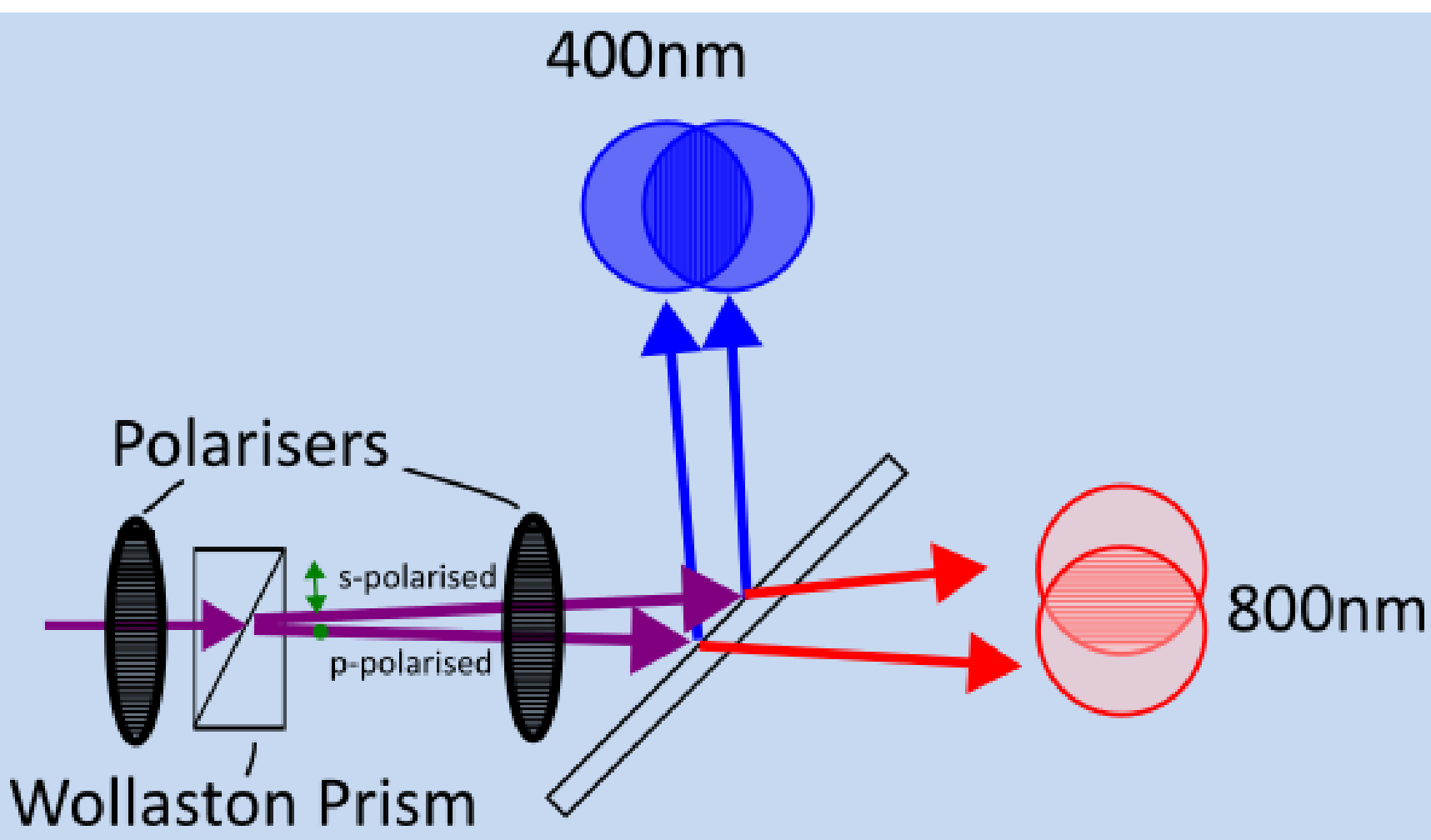


Phase space of Bayesian-optimised electron acceleration simulation using main beam parameters (a) (500 mJ, 45 fs) and (b) (900 mJ, 35 fs). (a) yields bunches of 200 MeV, 3.3 kA (b) yields 800 MeV, 5.2 kA, both yield ~100 pC bunch charge and percent-level energy spread.

## Diagnostic ensemble

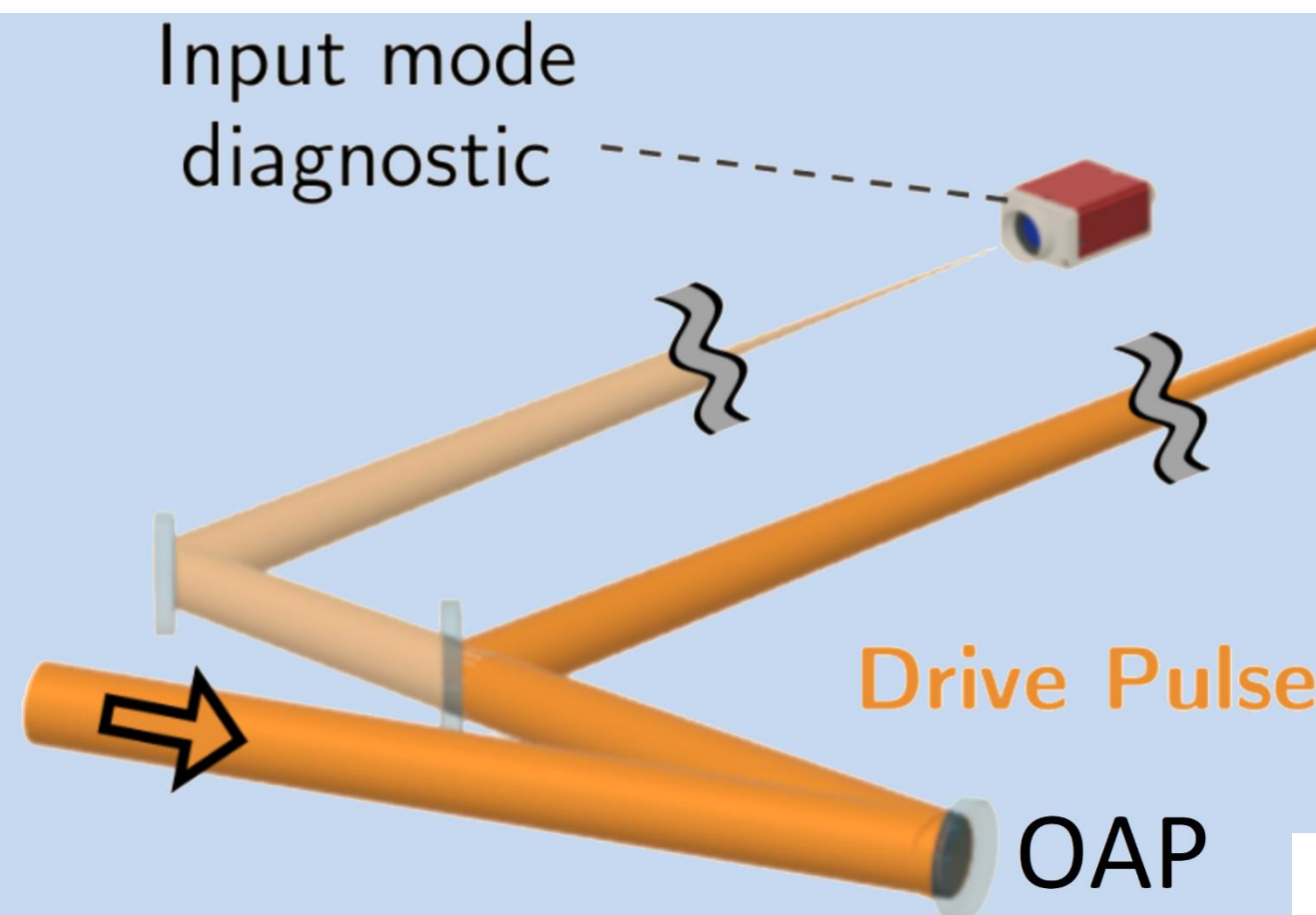
### Single-shot 2-colour Nomarski Interferometer

Used to characterise 10<sup>17</sup> cm<sup>-3</sup> CHOFI channel plasma & neutral density profiles with low (<10 mrad) phase noise in both colours [3].



### Input mode diagnostic

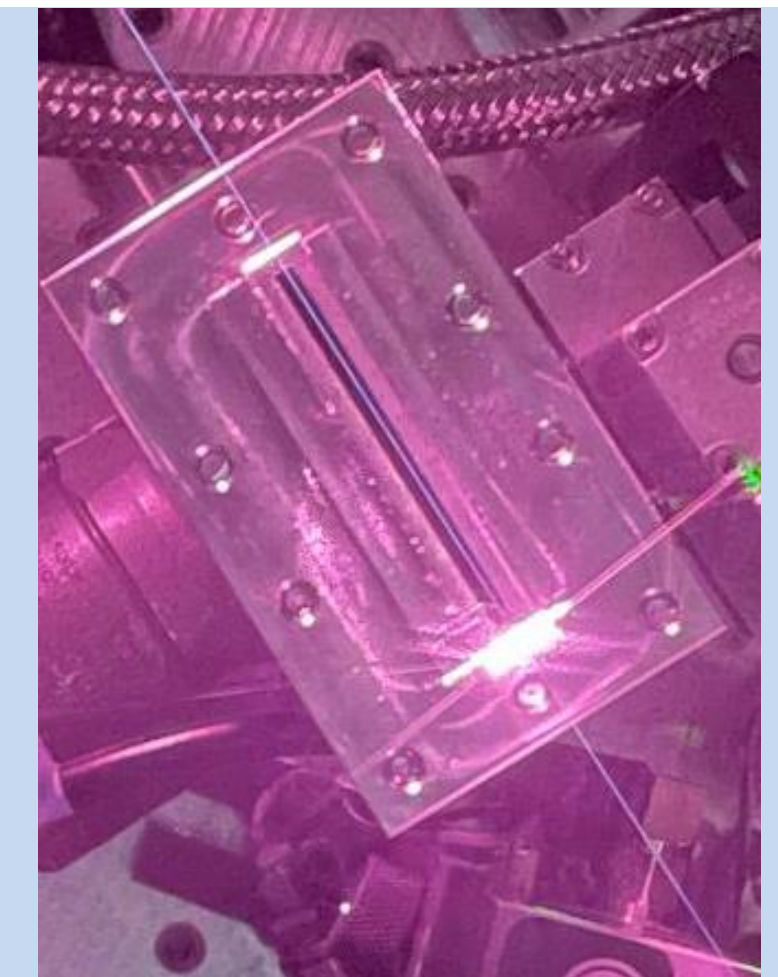
Used to measure pointing jitter of drive beam. Enables on-shot focal spot characterisation.



And much more...

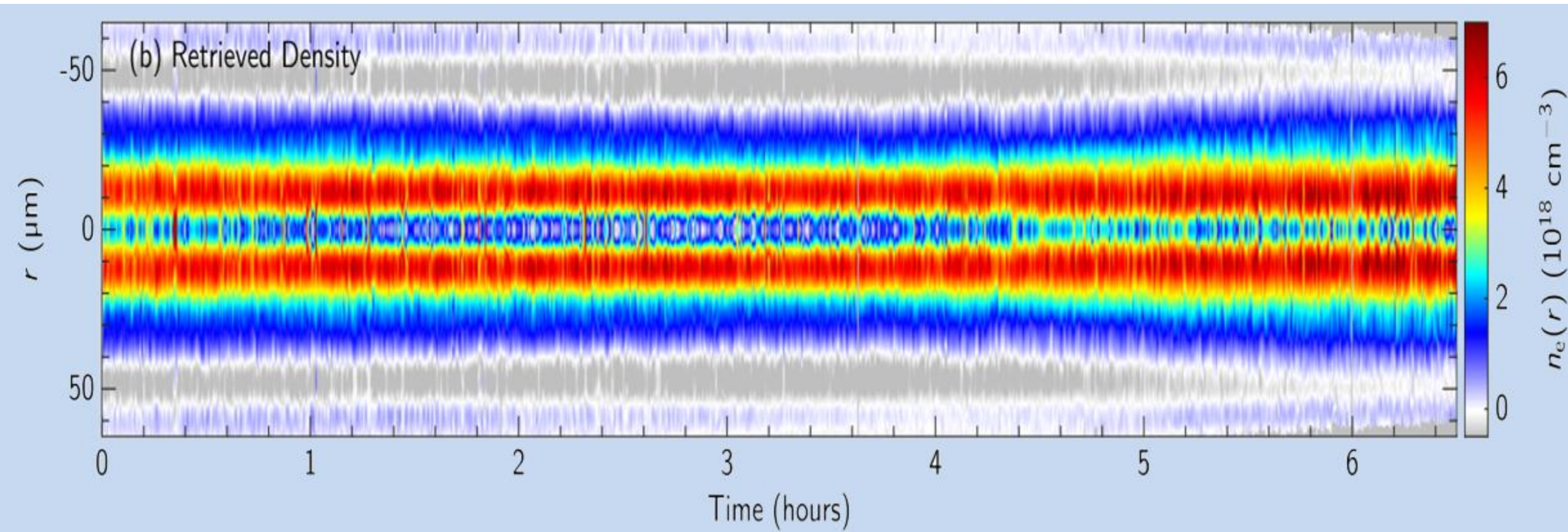
### Fluorescence camera

This camera is used to measure target longitudinal density profiles.

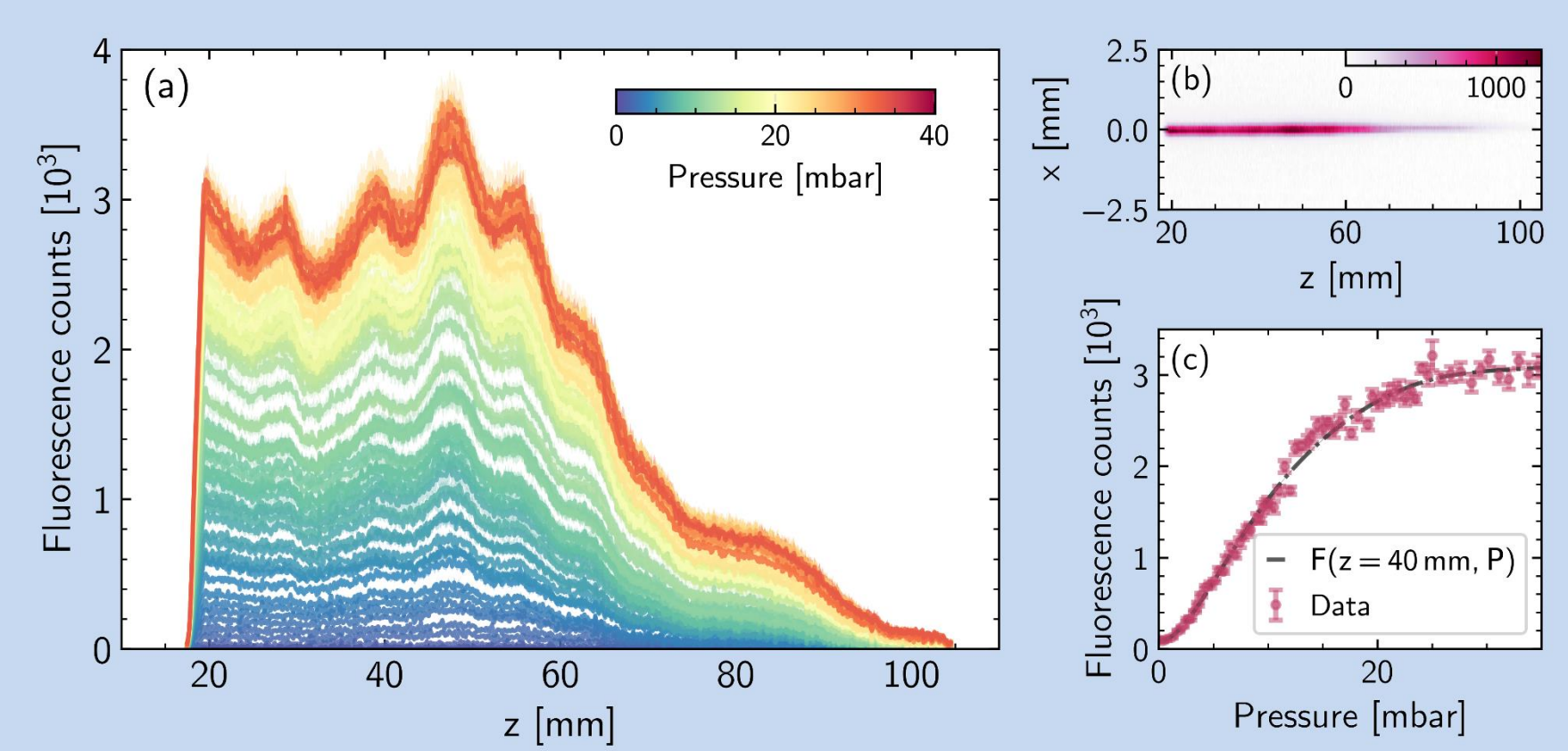


## First Results

OPAL kHz beamline demonstrated kHz operation of HOFI channels [1].

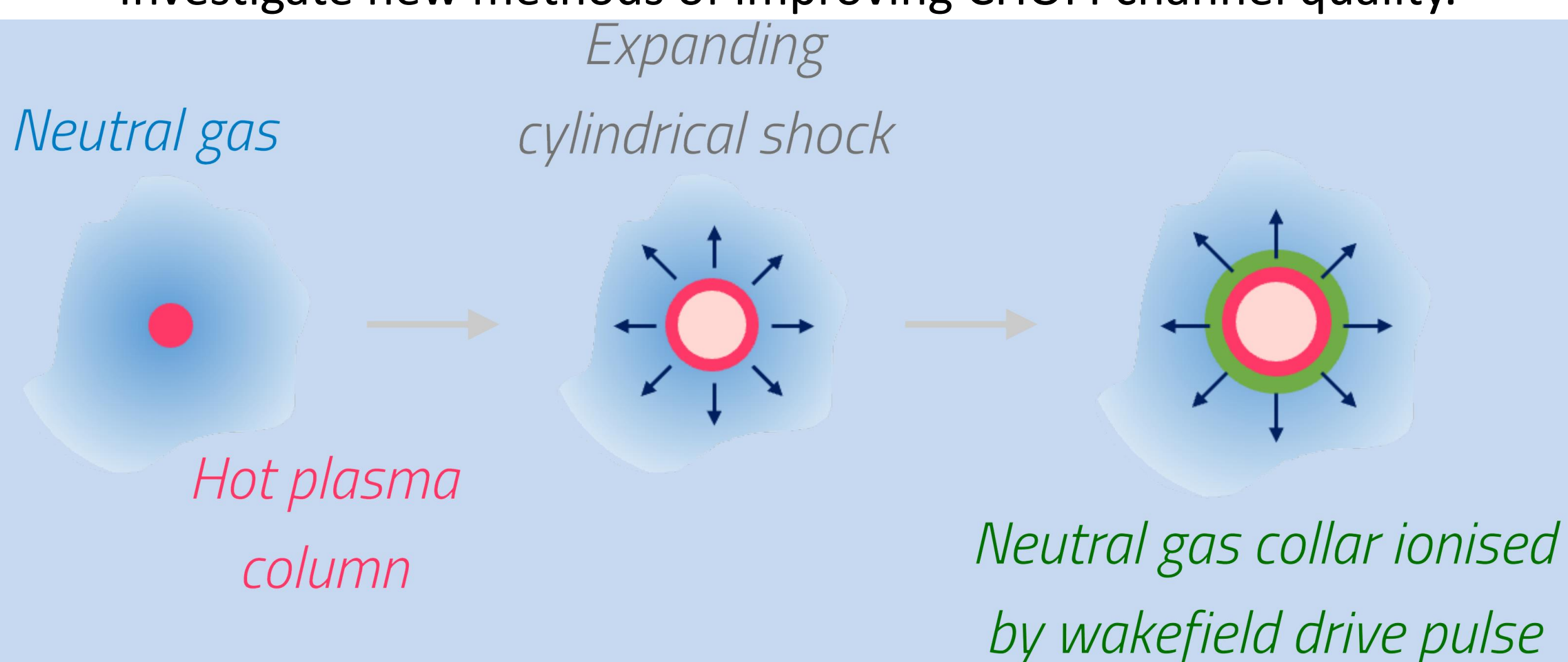


OPAL characterised truncated channel injection gas target uniformity [2].

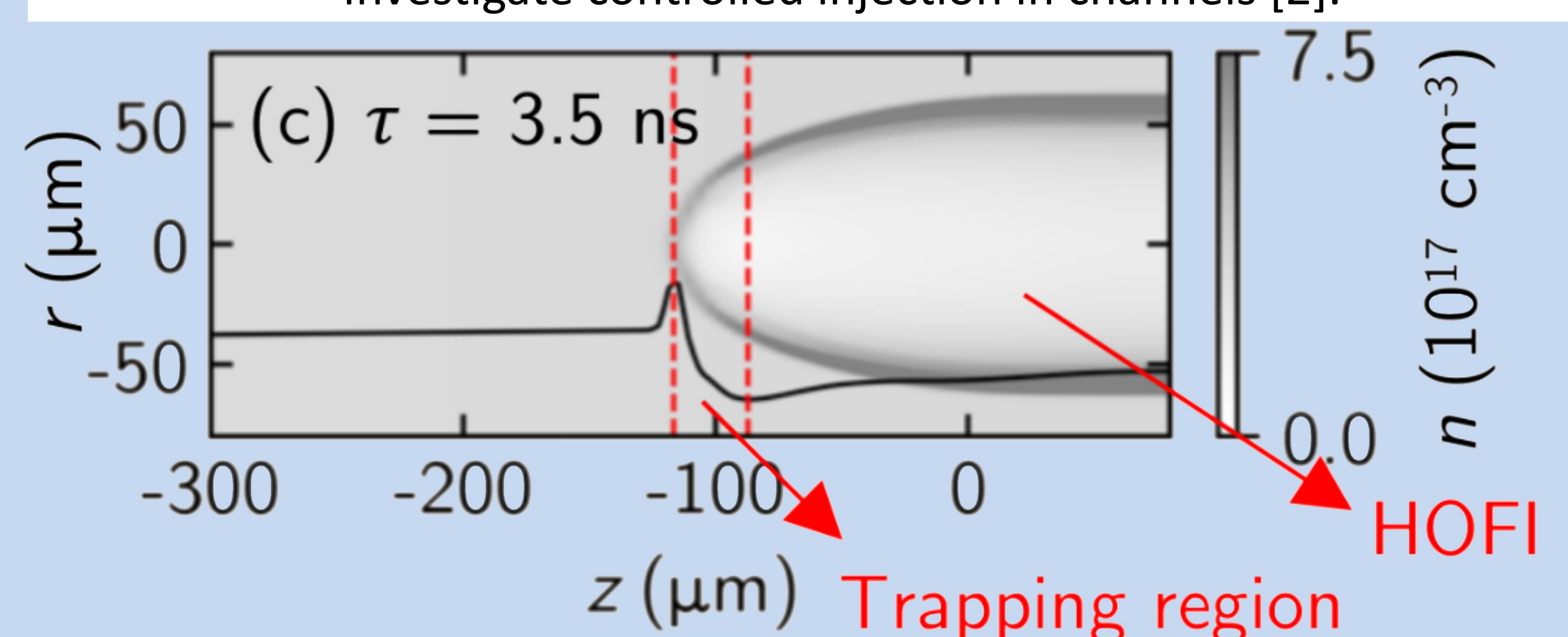


## Planned Experiments

Investigate new methods of improving CHOFI channel quality.



Investigate controlled injection in channels [2].



[1] Alejo, A., Cowley, J., Picksley, A., Walczak, R. & Hooker, S. M. Demonstration of kilohertz operation of Hydrodynamic Optical-Field-Ionized Plasma Channels. Phys. Rev. Accel. Beams 25, 011301 (2022).

[2] Picksley, A. et al. All-optical GeV electron bunch generation in a laser-plasma accelerator via truncated-channel injection. Preprint at <http://arxiv.org/abs/2307.13689> (2023).

[3] Liu, Q. et al. Application of Nomarski interference system in supersonic gas-jet target diagnosis. AIP Advances 11, 015145 (2021).

This work was supported by the Engineering and Physical Sciences Research Council (EPSRC) (Grant No. EP/V006797/1), the UK Science and Technologies Facilities Council (Grant ST/V001655/1), the Defence Science and Technology Laboratory (contract number DSTLX1000164172), and University College, Oxford (Oxford-Berman Graduate Scholarship.)