A systematic study of colliding plasmas for EUVL

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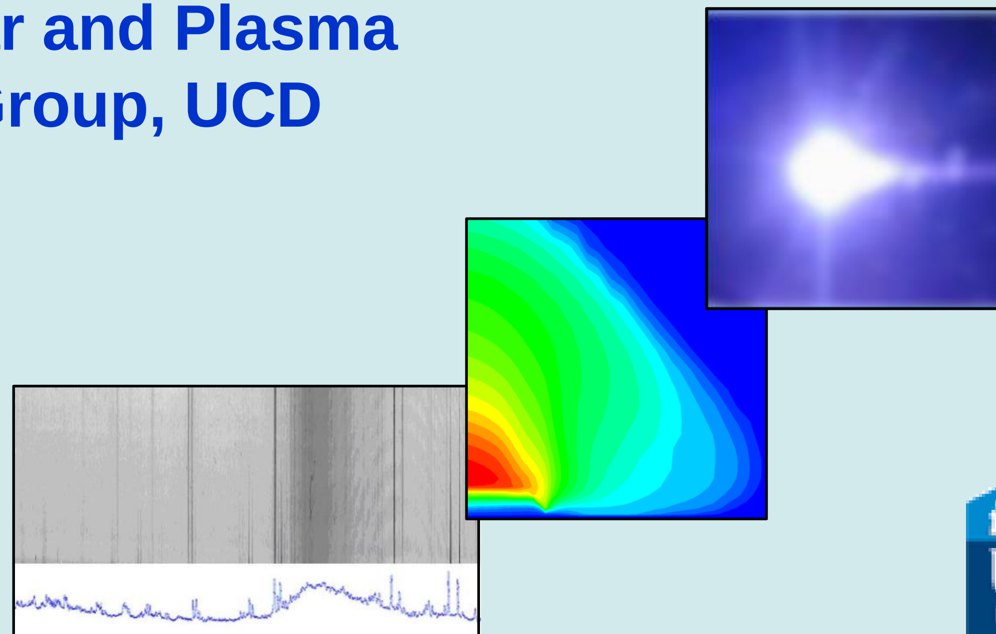

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November 5th 2013

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Outline

Motivation

Experimental Set-Up

Results/Discussion

Prospects

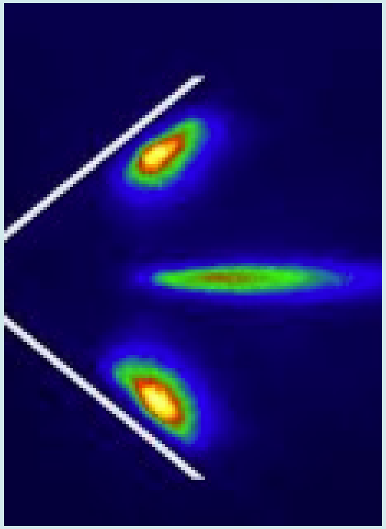
Colm O'Gorman

Thomas Cummins

Paddy Hayden

Motivation

- Colliding Plasmas can create a stagnation layer



$$\zeta = \frac{D}{\lambda_{ii}}$$

Hough *et al* J. App. Phys **107** 024904 (2010)

Where λ_{ii} is the ion-ion mean free path

$$\lambda_{ii}(1 \rightarrow 2) = \frac{\left(m_1 v_{12}^2\right)^2}{4\pi e^4 Z^4 n_2 Ln(\Lambda_{12})}$$

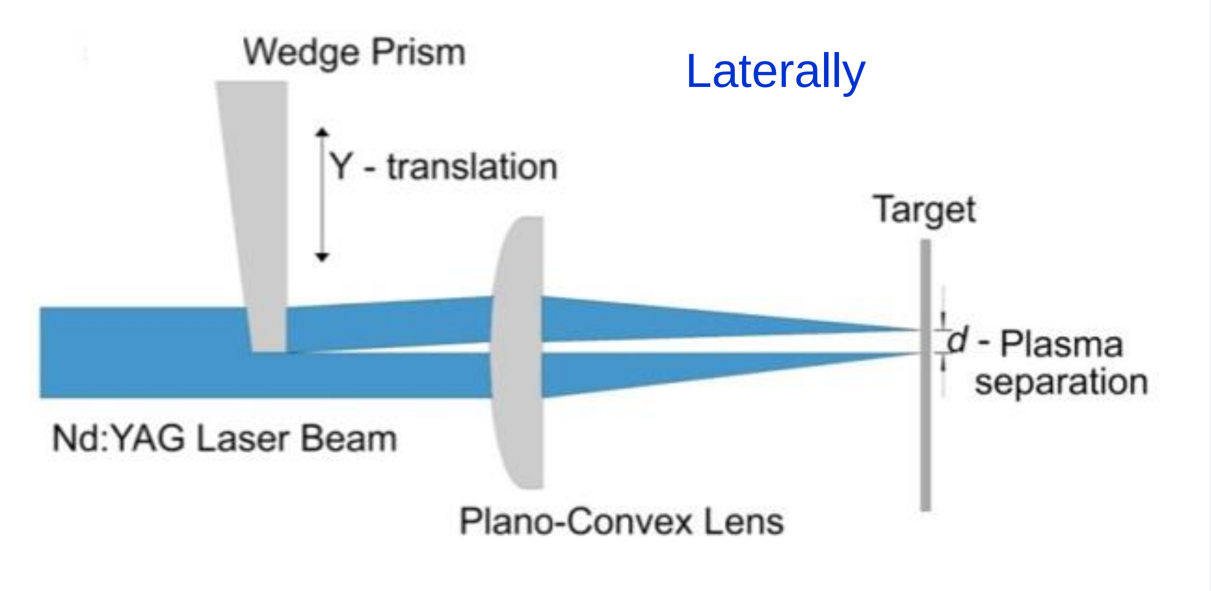
Expect strong stagnation for counter streaming plasmas where λ_{ii} is small in comparison to the ablation front separation.

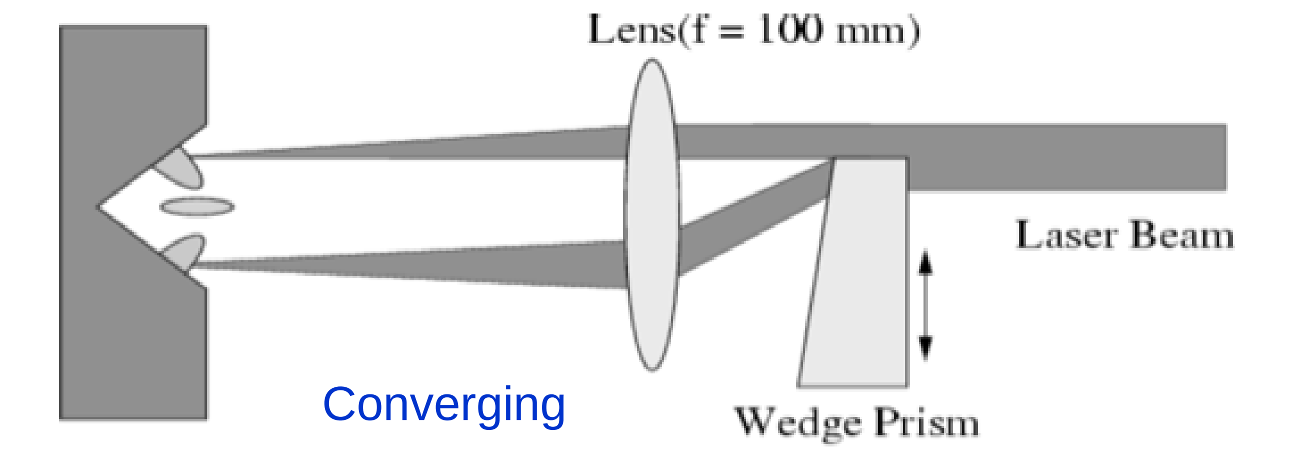
Rambo and Denavit, Phys. Plasmas **1** 4050 (1994)

Motivation • Colliding plasma configurations

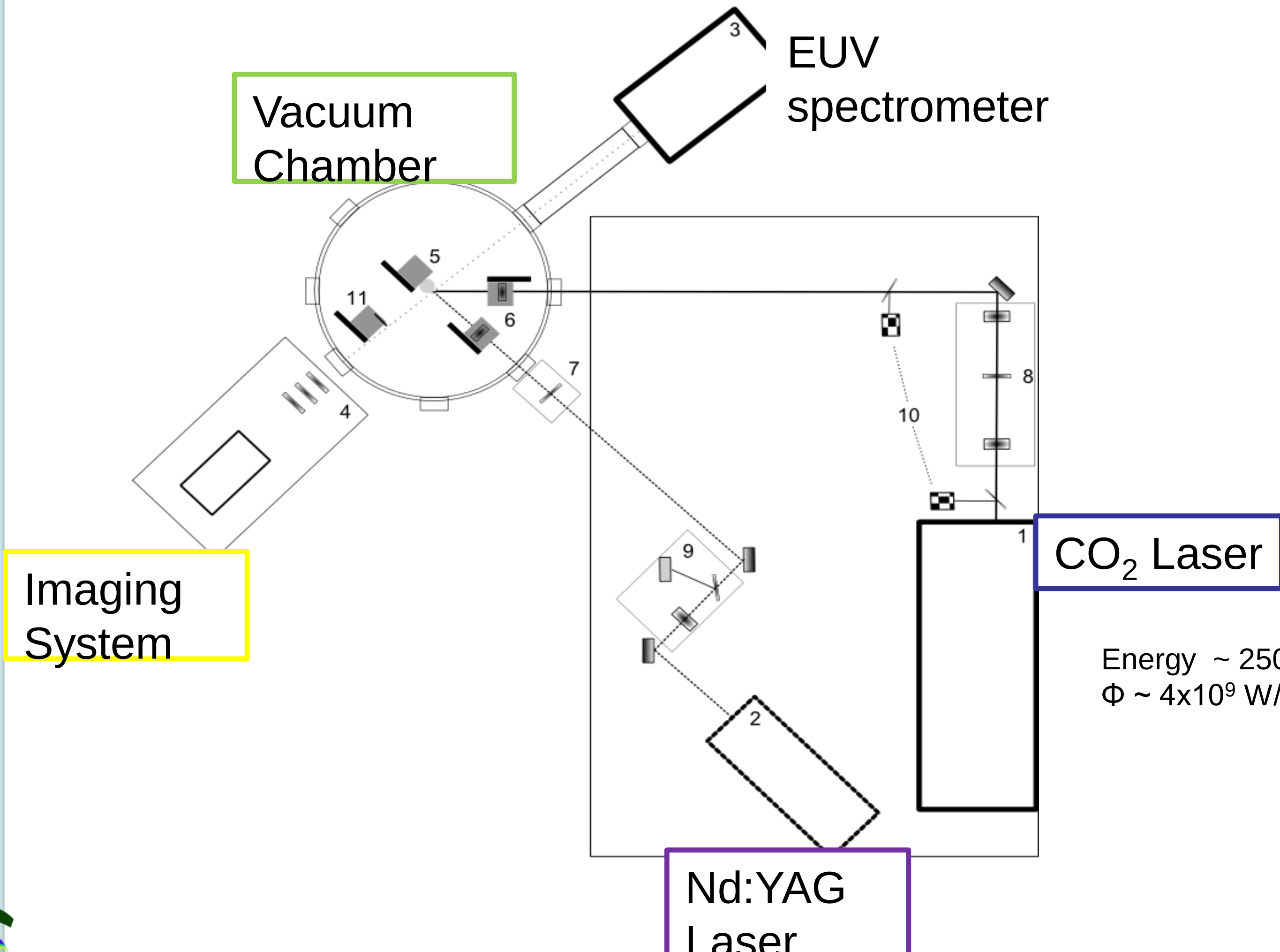
Variable Parameters

Plasma separation
Laser intensity
Wedge angle
Laser wavelength





Experimental set-up



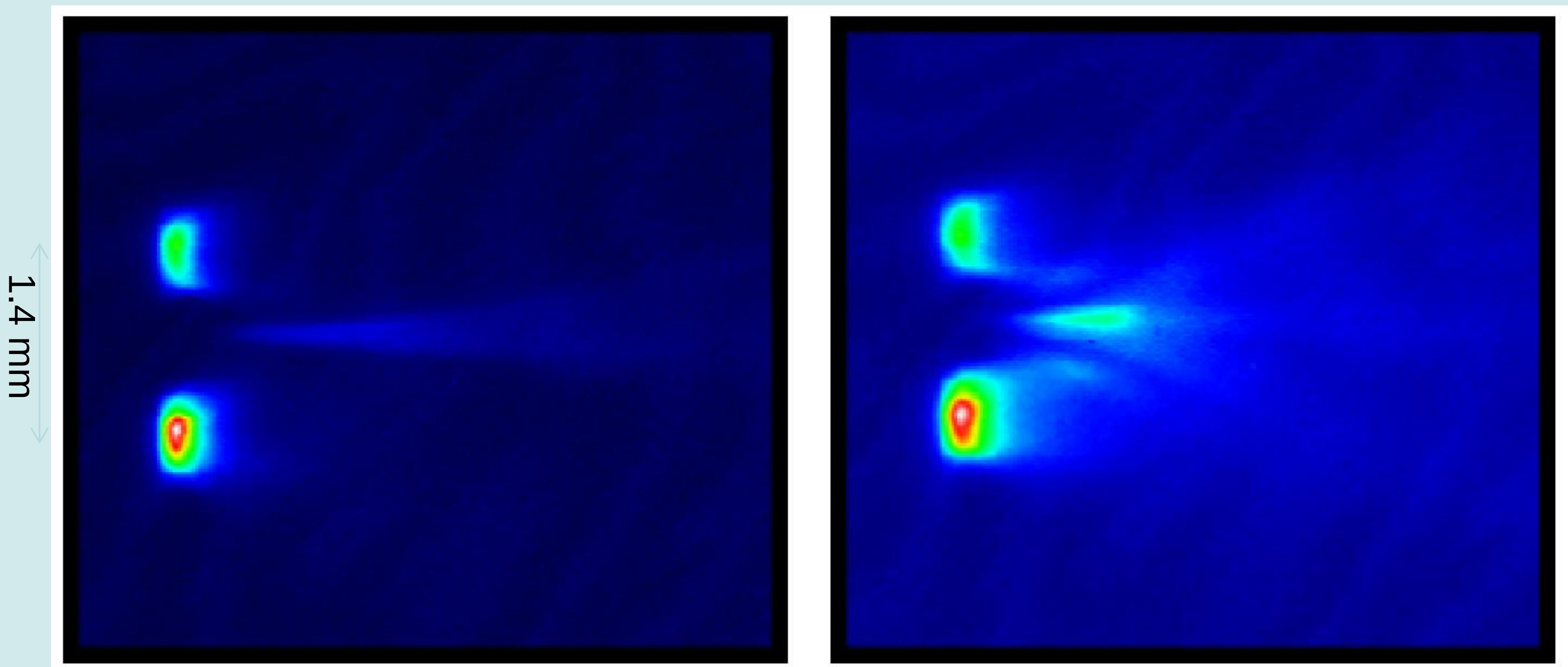
Energy ~ 250 mJ
Φ ~ 4×10^9 W/cm^2

Energy = 491.9 mJ, 269 mJ, 134.7 mJ
Φ ~ 1.15×10^{11}, 6.20×10^{10}, 3.09×10^{10} W/cm^2

Results: Flat target CP – visible imaging

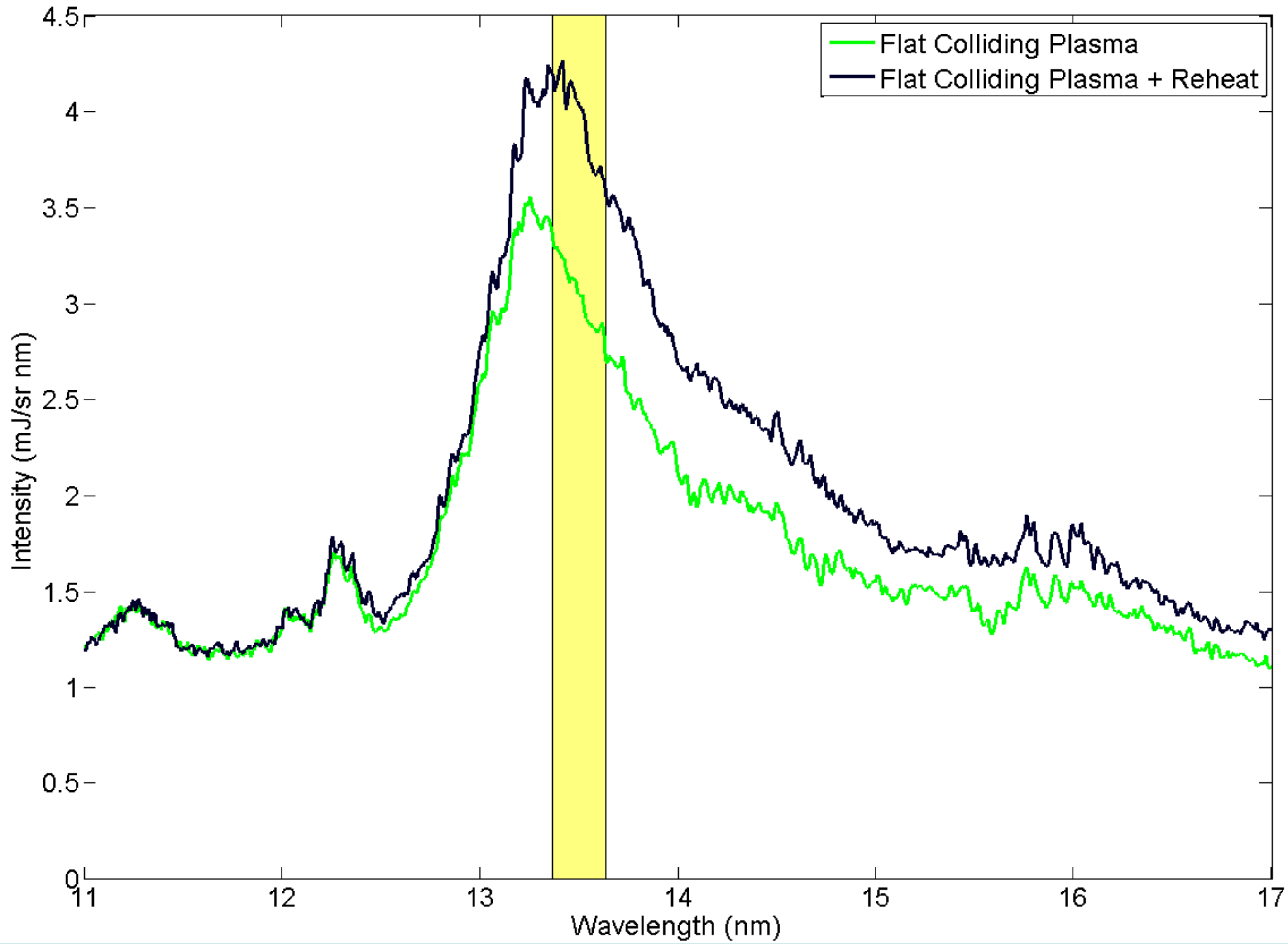
Nd:YAG colliding plasma

Nd:YAG colliding plasma
+ CO_2 reheat



Imaging system sensitive to light in 400 – 500 nm range.

Results: Flat CP and reheat spectra



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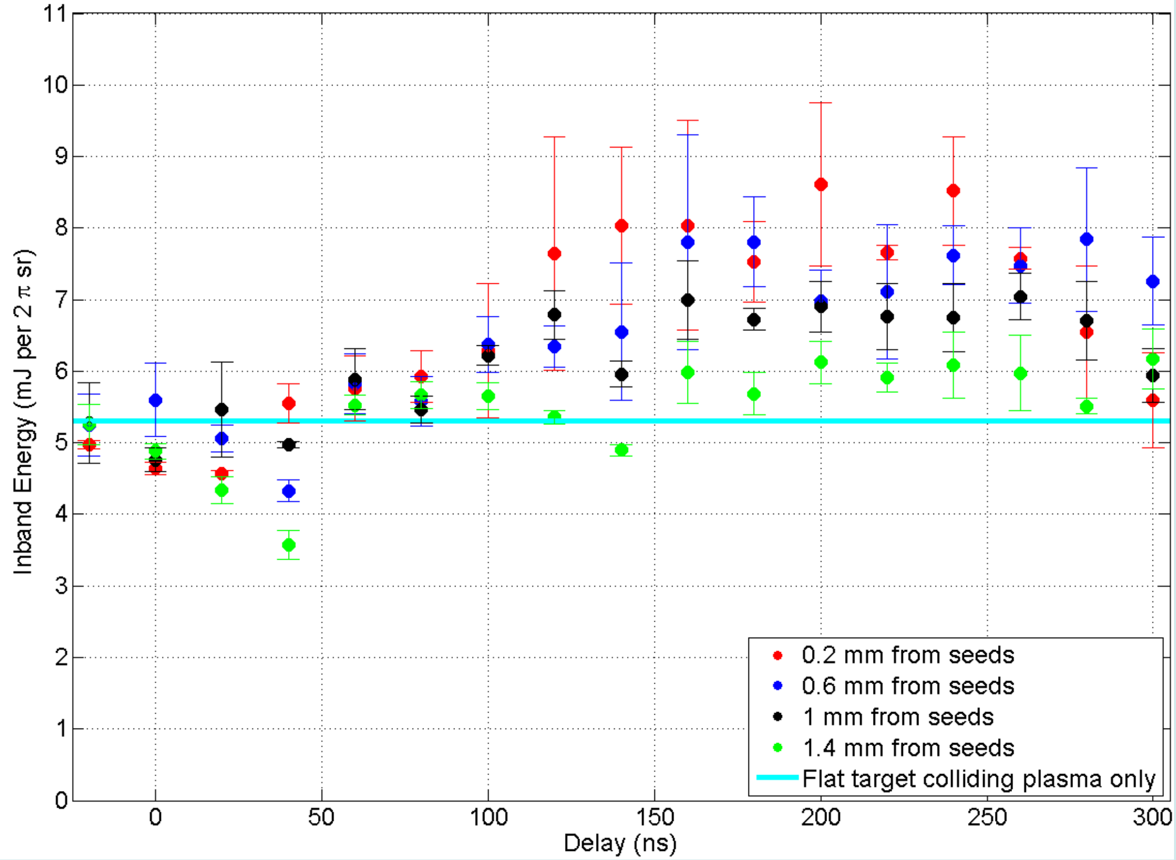
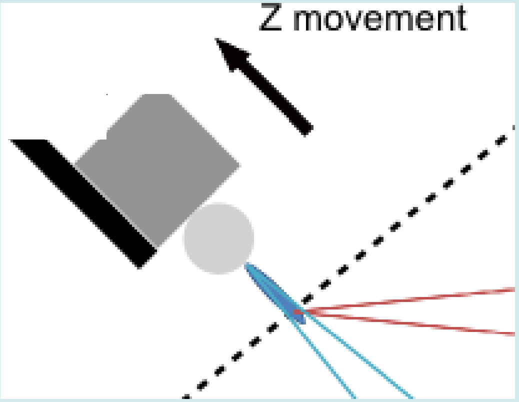
Systematic study: Flat target

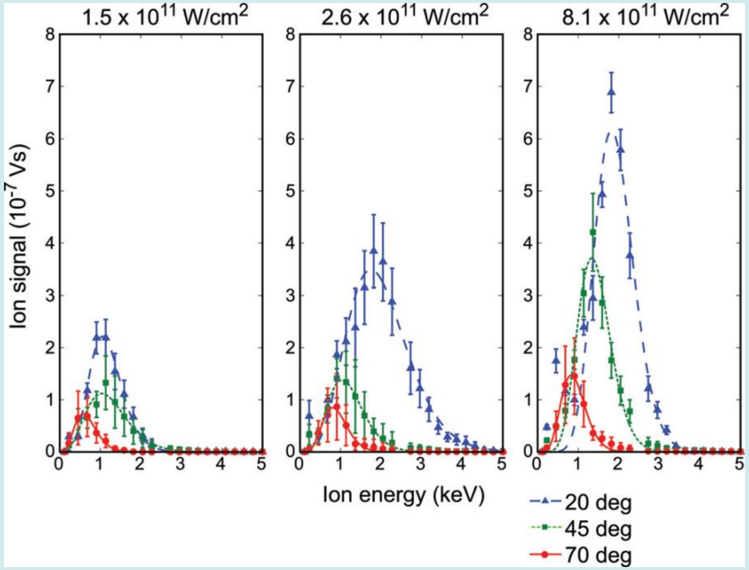
varied delay times and CO_2 positions



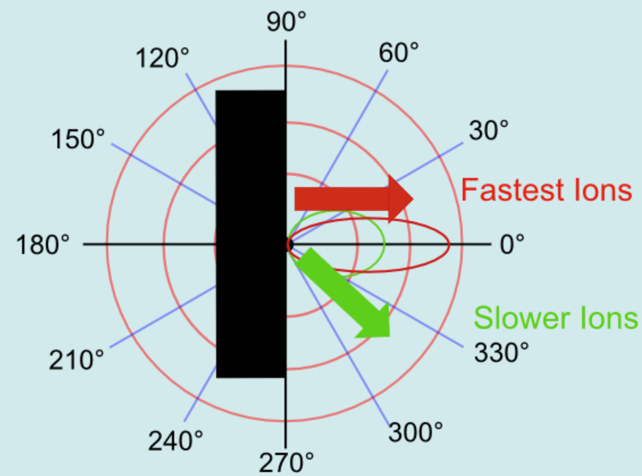


Maximum Total CE of 1.4 %

Ion Spectroscopy Measurements



Aodh O'Connor PhD Thesis UCD (2009)



For normal laser incidence

- •Highest ion current is target normal
- •Highest ion KE is target normal
- •Larger angles – Lower KE

•Stagnation layer results from the interaction between two plumes

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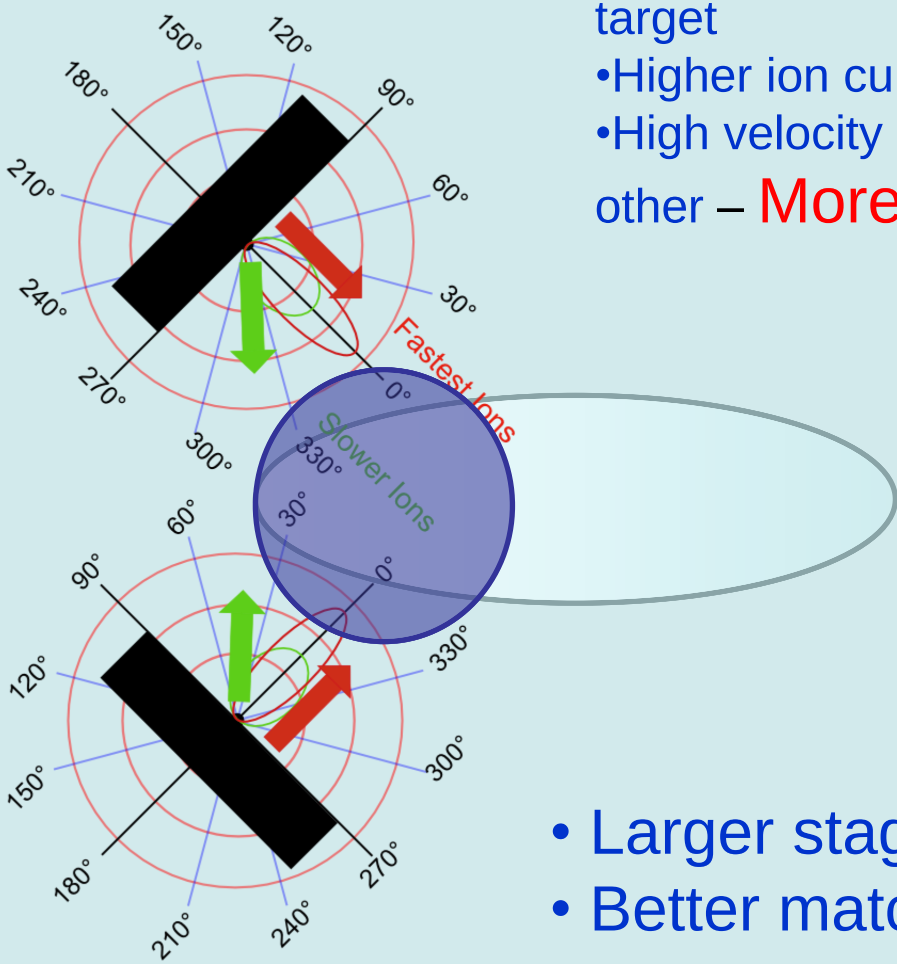
Wedge target

•Turn targets towards each other – Wedge target
•Higher ion current towards each other
•High velocity ions are travelling towards each other – More interpenetration



• Larger stagnation layer
• Better matching to CO_2

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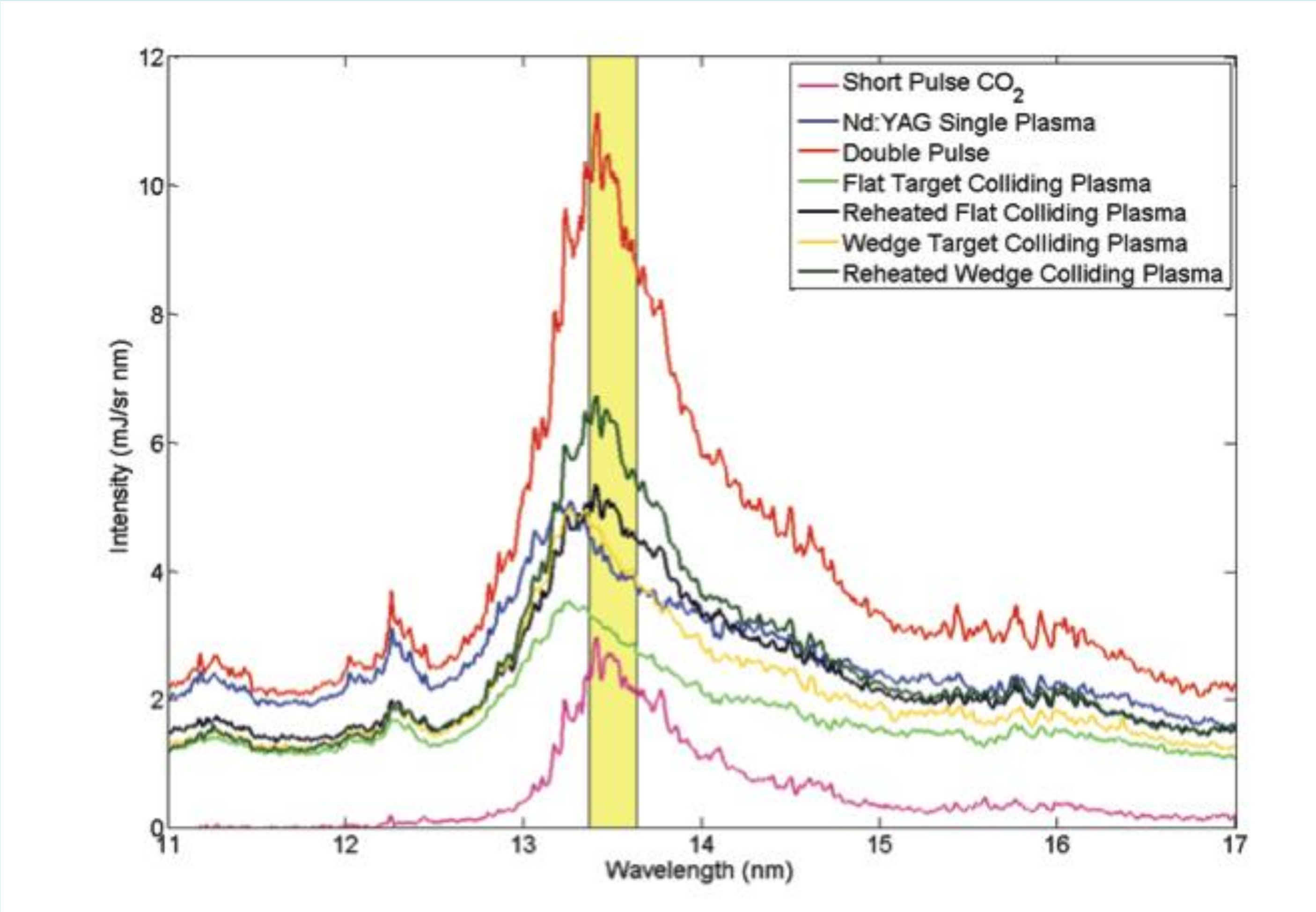
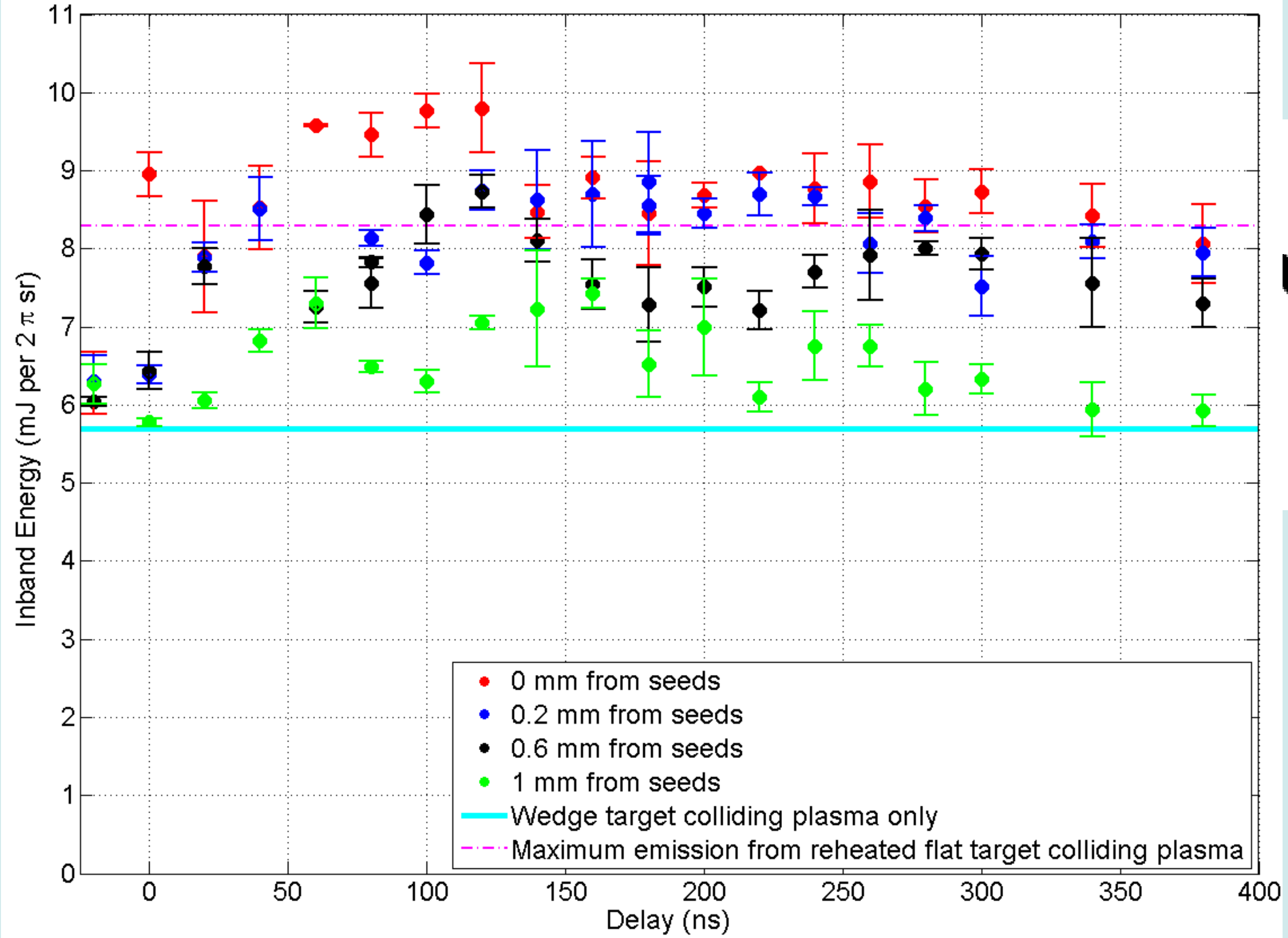
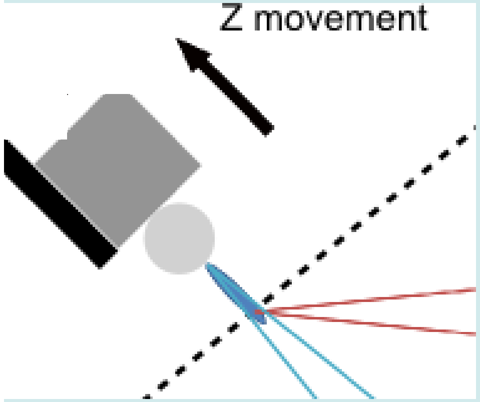
Results: Comparison of Spectra



Systematic study: Wedge target

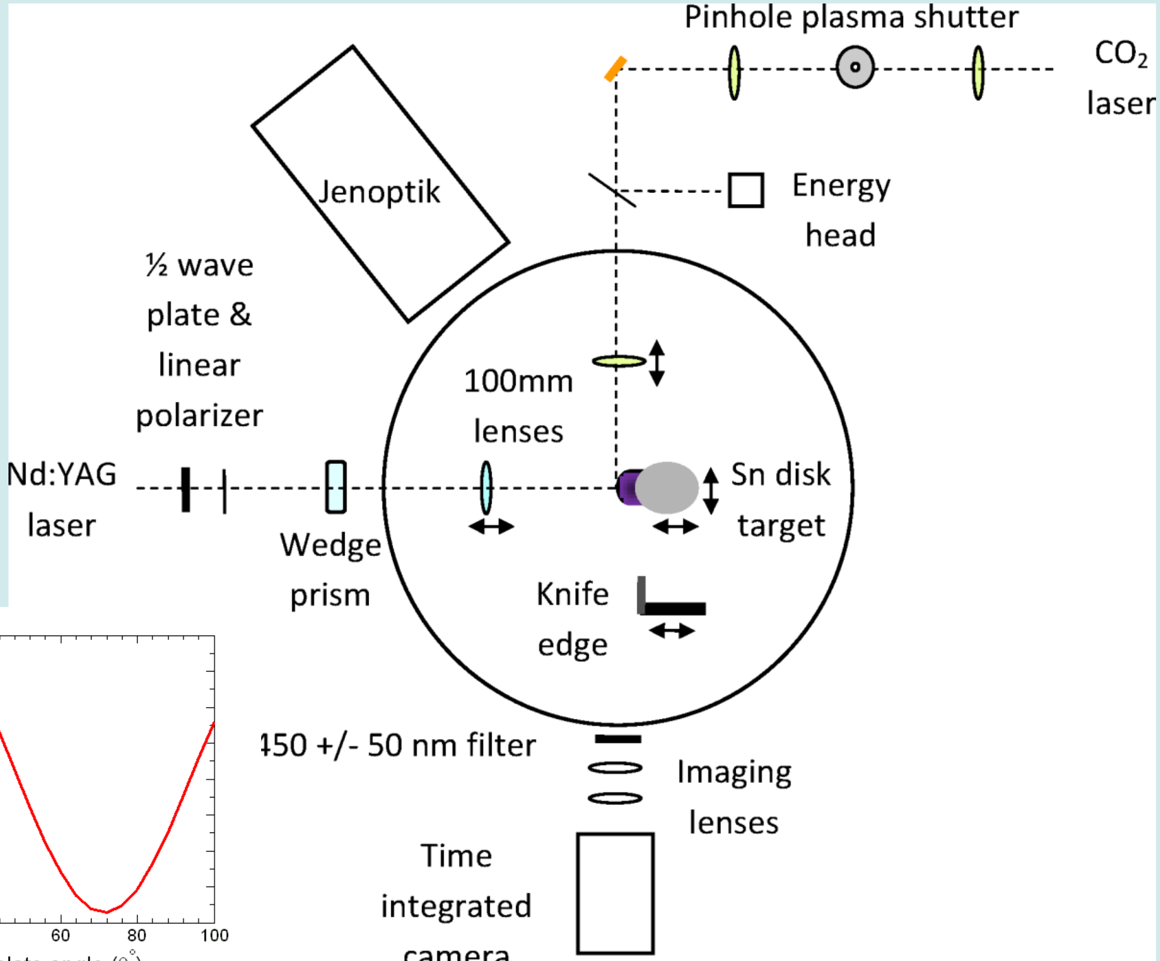
varied delay times and CO_2 positions

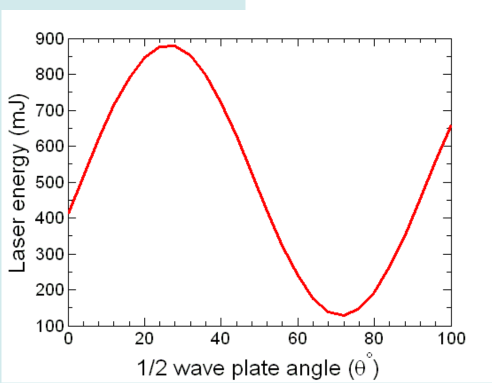




Maximum Total CE of 2.1 %

More Optimal Experimental Arrangement





Results:

EUV output wedge target (YAG = 270 mJ)

- 18.7 mJ max in-band from re-heat
- 5.5 mJ average output from colliding plasma only generated by Nd:YAG
- 13.2 mJ in-band is a 4.9% CE of CO_2 laser energy in EUV photons

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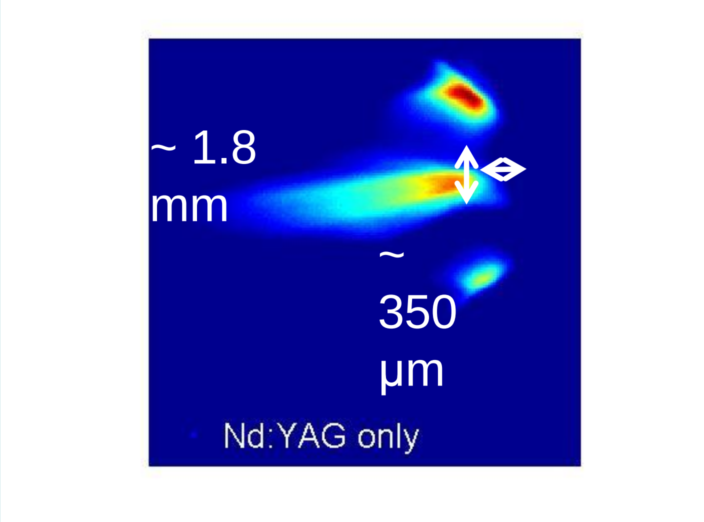
Future Prospects:

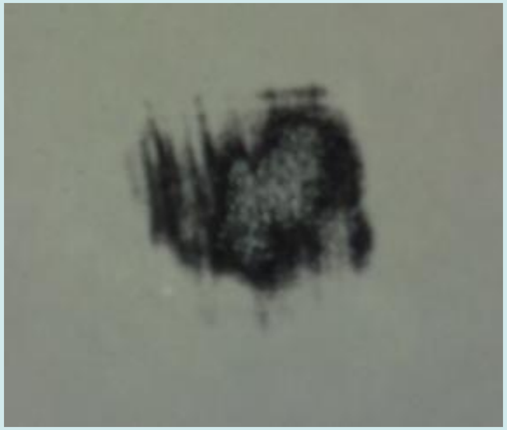
- Interaction region size compared to CO_2 pulse.

Calculated 500 μm and measured 520 μm beam diameter at experimental focus

- CO_2 spatial profile

- Parameter space





Thanks

SFI for financial support (07/IN.1/B1771)

UCD Spectroscopy Group

Workshop Staff in UCD

Collaborators in DCU

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