Laser Plasma Pumping by Varying-length CO_2 Laser Pulses

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1.Introduction

- Research to date [1] has identified CO_2 laser produced plasmas (LPPs) of Sn as a viable Extreme Ultra-violet Lithography (EUVL) source candidate
- CO_2 LPPs have demonstrated an increased in-band conversion efficiency (CE) when compared to the Nd:YAG, due in the main to reduced opacity effects [2]
- Altering the density scale length of the target by using droplet or plasma targets have demonstrated improved absorption of the incident CO_2 pulse as compared with planar targets with a CE of 4% reported [3]
- Plasma confinement using wedge targets have shown a CE of 5% [4]. However numerical simulations have shown the possibility of further increasing the CE for CO_2 LPPs to 7% [5]

Experimental parameters

Nd:YAG pre-pulse: 10 mJ (5 x 10^8 W/cm²) and 290 mJ for 2 spot diameters

TEA-CO_2 pump laser: 290 mJ in 60 ns (1.2 J in 500 ns total pulse)

Delay between pulses: 0 ns–2 μs

Timing jitter: ~15 ns

Spectrometer range: 9.6–18 nm

Focussing: f/10 cm lenses for both lasers

2.Experimental set-up

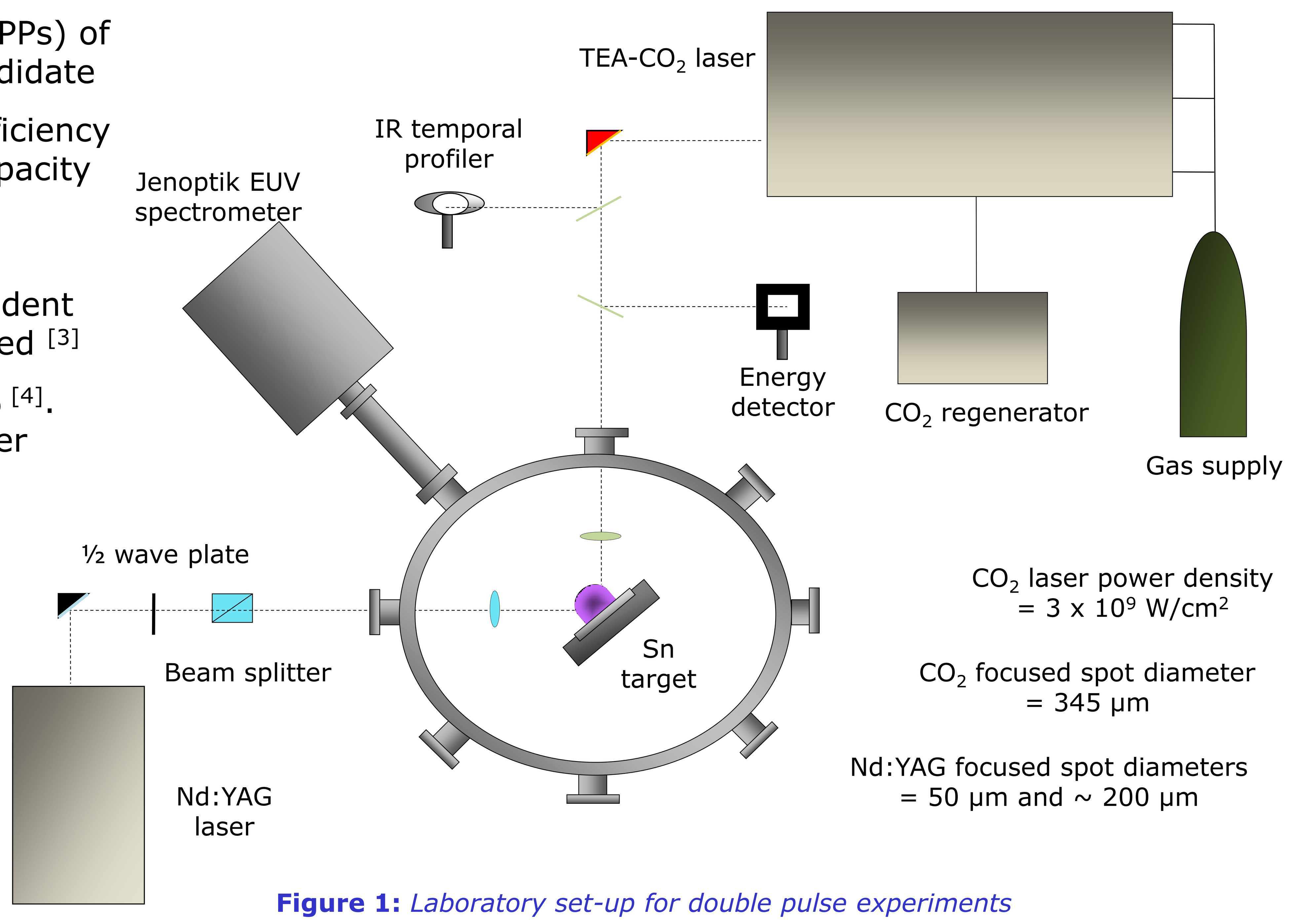

Figure 1: *Laboratory set-up for double pulse experiments*

3.Results

- The interaction of the CO_2 main pulse with the Nd:YAG seed plasma resulted in maximum CE of 2.5% compared to 1.7% on planar targets
- CE is lower than reported due to low power density of TEA-CO_2 laser, 4 x 10^9 W/cm²

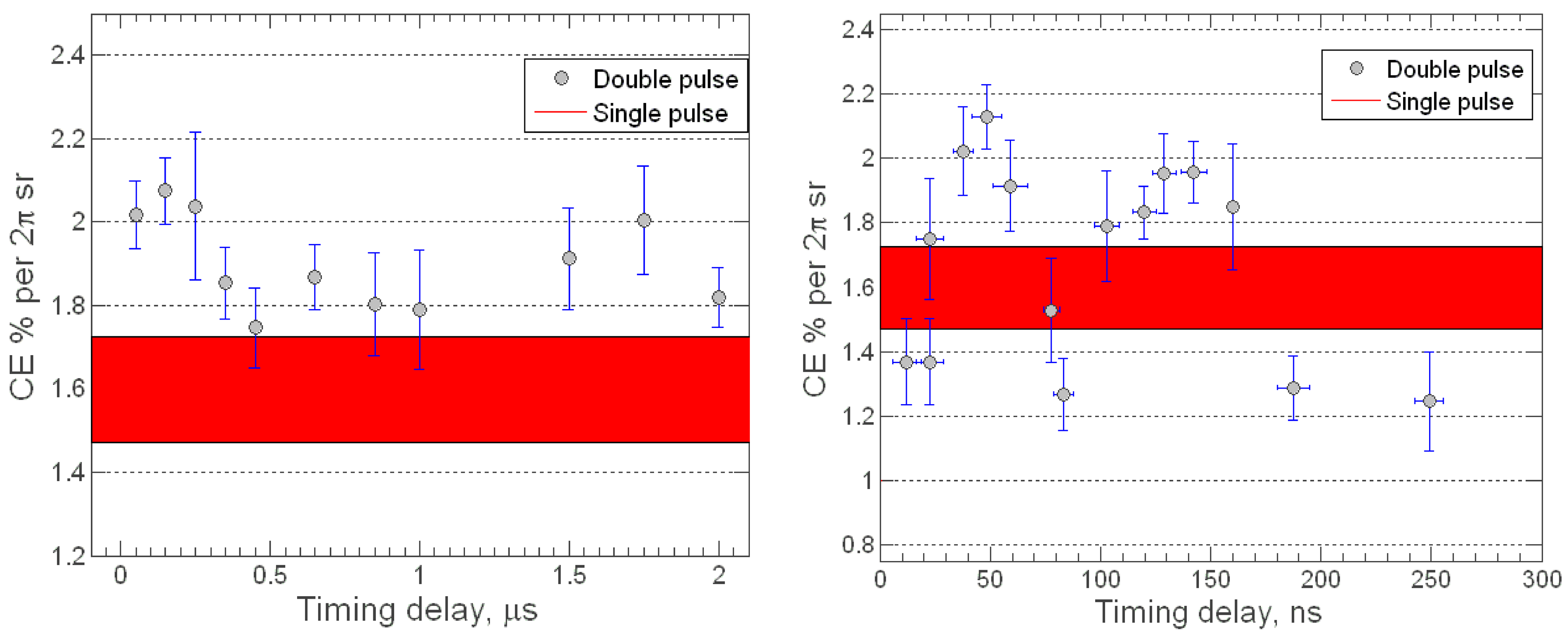

Figure 2(a) & (b): *Double pulse CE observed using 300 mJ out of focus and 10 mJ tightly focussed Nd:YAG seed plasma*

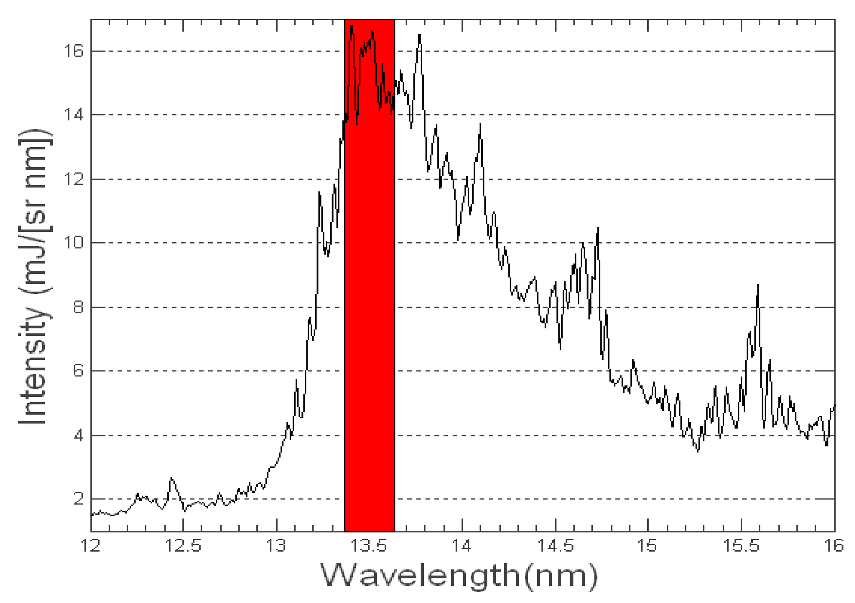

Figure 3: *Double pulse Sn spectrum*

- Fig. 3 shows how optically thin the plasma produced is in the in-band region
- This shows the ability to increase the on target laser intensity further without self-absorption
- Atomic modelling codes can be used to confirm these features in the 13.5 nm band

- A novel and simple plasma shutter device Fig. 4, has been developed
- Pulses are clipped by focussing them onto highly reflective surfaces
- Durations as low as 2 ns achieved

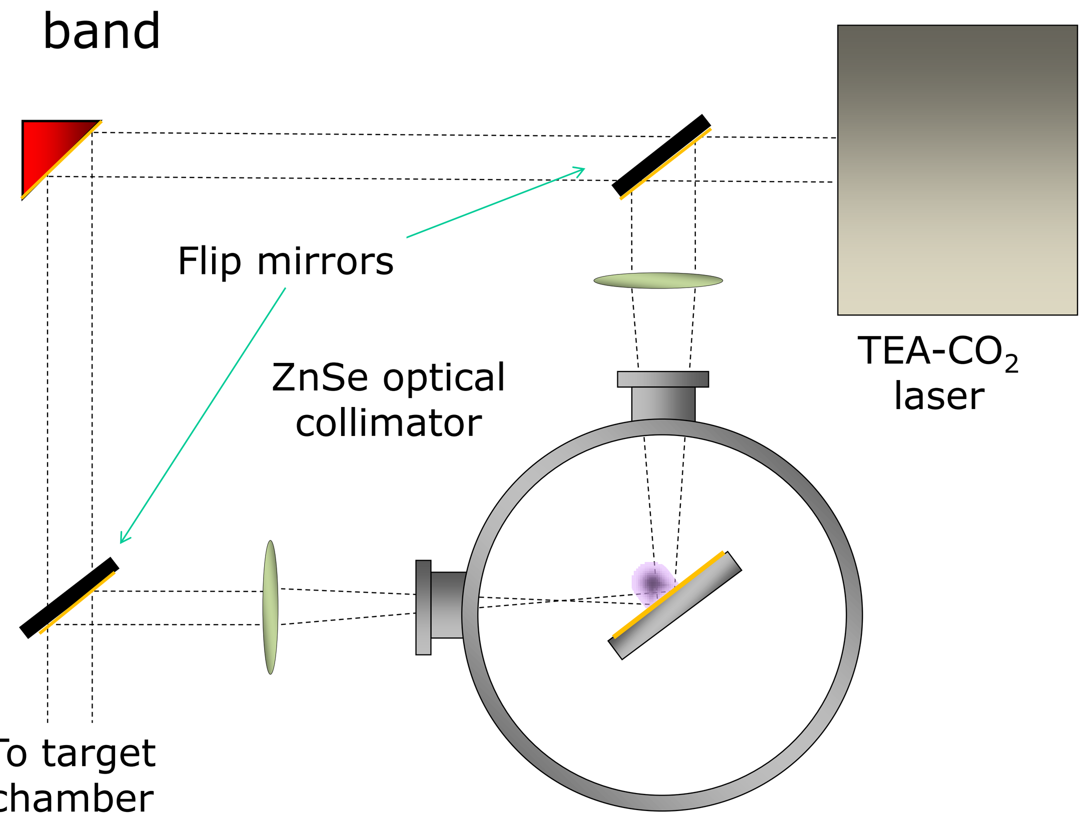

Figure 4: *Schematic of pulse shortening chamber*

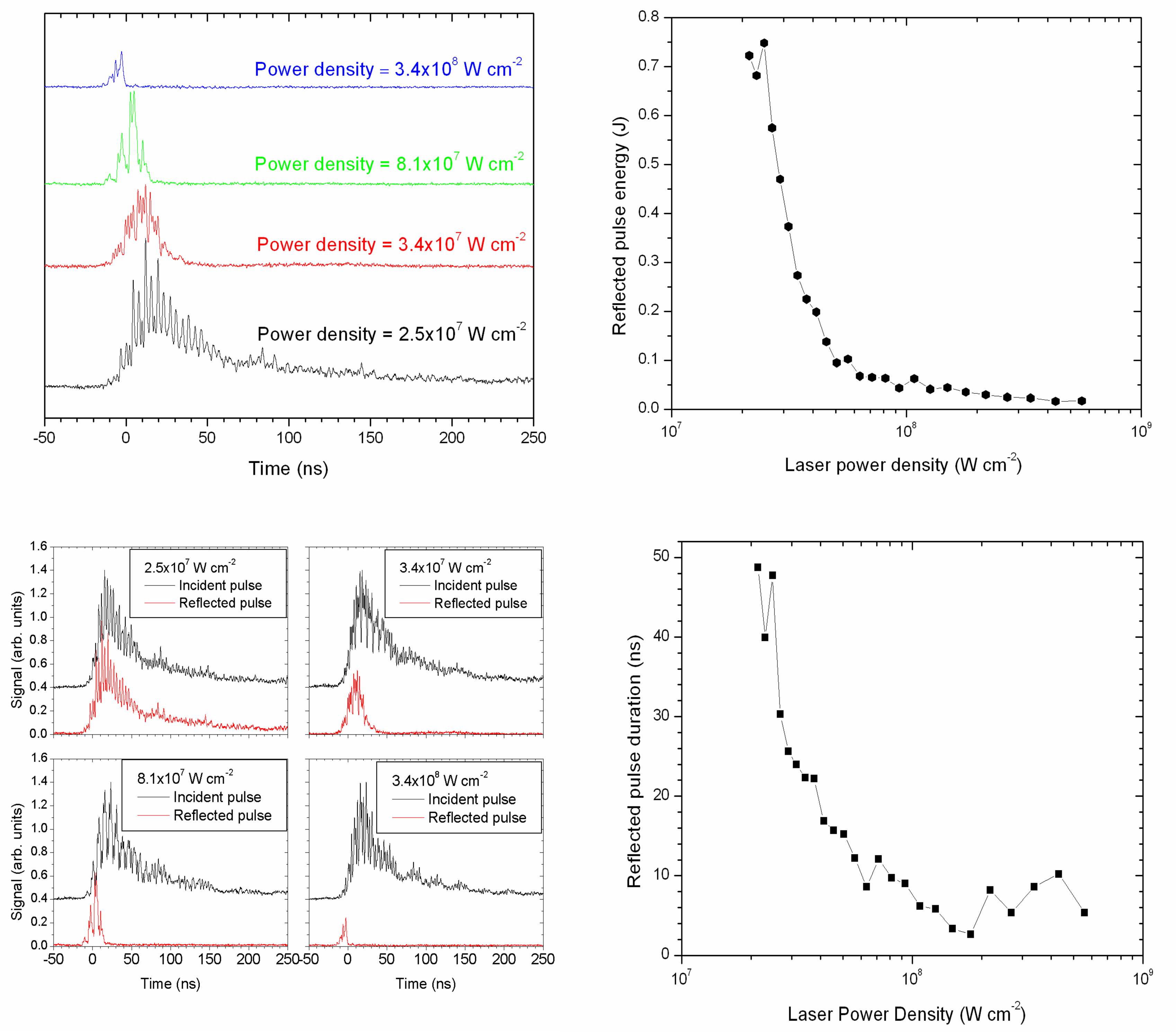

Figure 5(a),(b),(c) and (d): *Resulting reflected pulses for various power density incident on reflector surface by varying lens position*

- These shortened pulses can be passed through an amplifying medium to increase the energy and hence pulse intensity
- Improved CO_2 pulses will be incident on a range of novel solid, mass limited and plasma targets for further EUV research

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Acknowledgements: This work was supported by Science Foundation Ireland under grant number 07/IN.1/I1771

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