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Evolution of Relativistic Plasma Wave-Front in a LWFA

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(Presented by **Chris Clayton**)

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Thank to: Chris Clayton, Ken Marsh, Joe Ralph, Art Pak
Wei Lu, Frank Tsung

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Introduction

- The complete nonlinear evolution of a plasma wake driven by an intense laser pulse is of great interest.
- Subtle and continuous changes in the properties of the channeled laser pulse will affect the phase velocity of the trailing wake.
- We investigate these subtle changes of the leading edge of the plasma wake: in particular, the velocity and amplitude of this so-called ‘wave-front’.

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Tools and Parameters

Diagnostics…

- Time/space resolved shadowgraphy.
- Time/space resolved interferometry (low n_e).
- Time/space/ω resolved transverse Thomson scattering (high n_e).
- Forward-scattered pump-laser spectrum.
- Forward-emitted electrons.

Ti:Sapphire Laser and He gas…

- 2 TW $< P_0 <$ 3 TW; $w_0 = 10\ \mu m$; $\tau = 45 \pm 5 fs$; $\tau_{pr} = 55 \pm 5 fs$
- $1.3 \times 10^{18} < I_0 < 1.9 \times 10^{18}$ W/cm^{-2}
- $0.96 < a_0 < 1.2$
- $n_e = 1.3 \times 10^{19}$ cm^{-3} (low ne).
  - 1.5mm gas jet
- $n_e = 5 \times 10^{19}$ cm^{-3} (high ne).
  - 2.0mm gas jet

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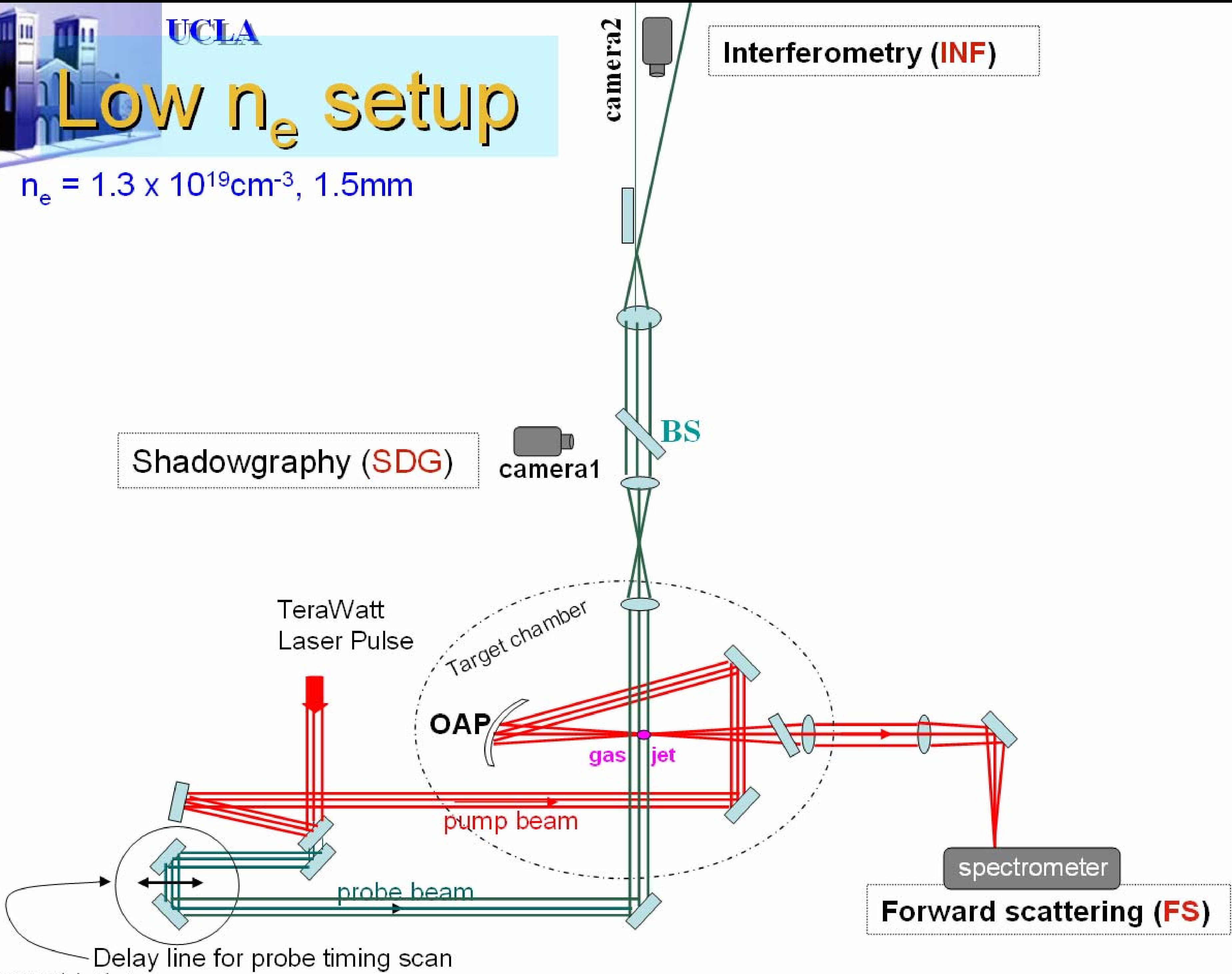
Low n_e setup

$n_e = 1.3 \times 10^{19} cm^{-3}$, 1.5mm



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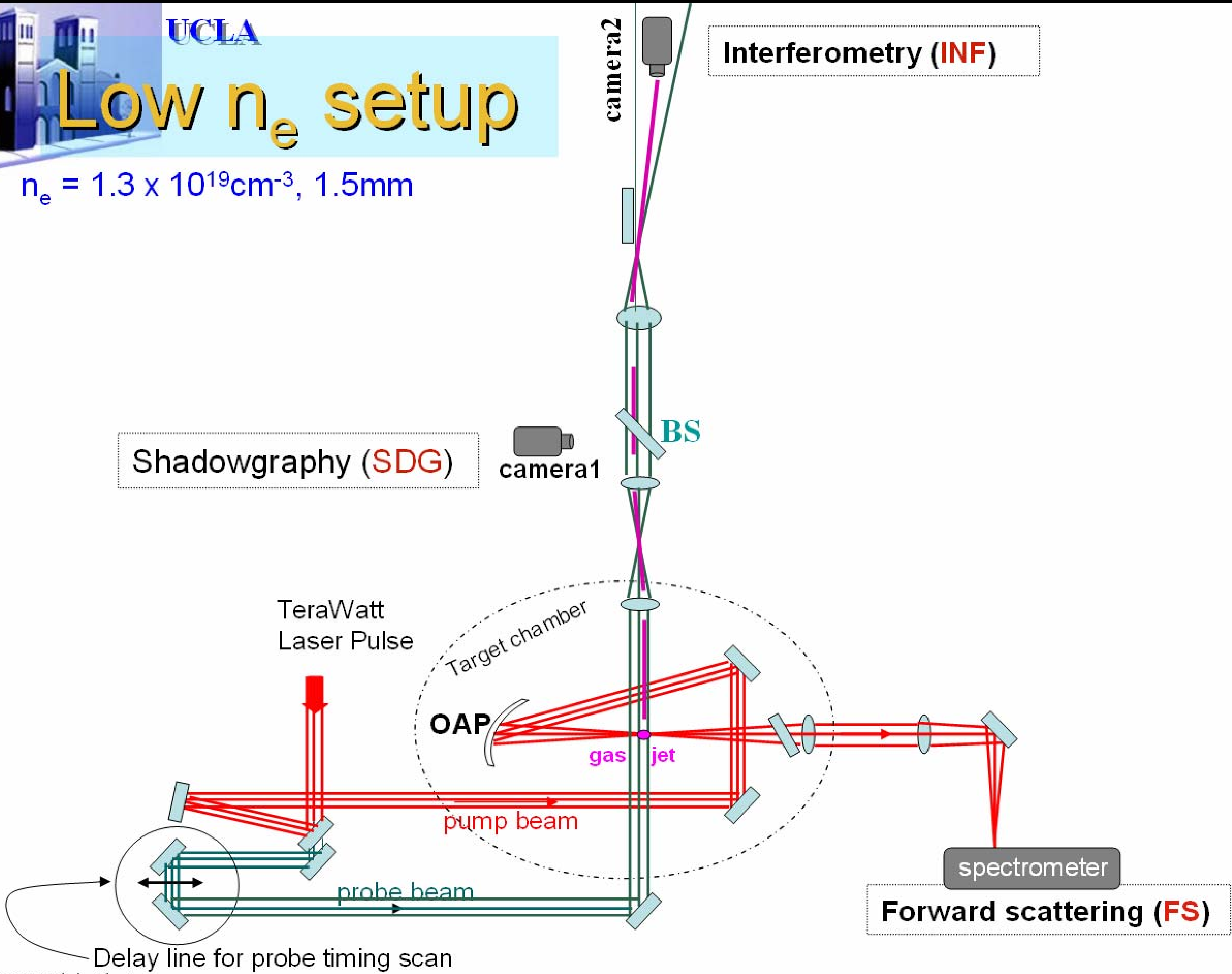

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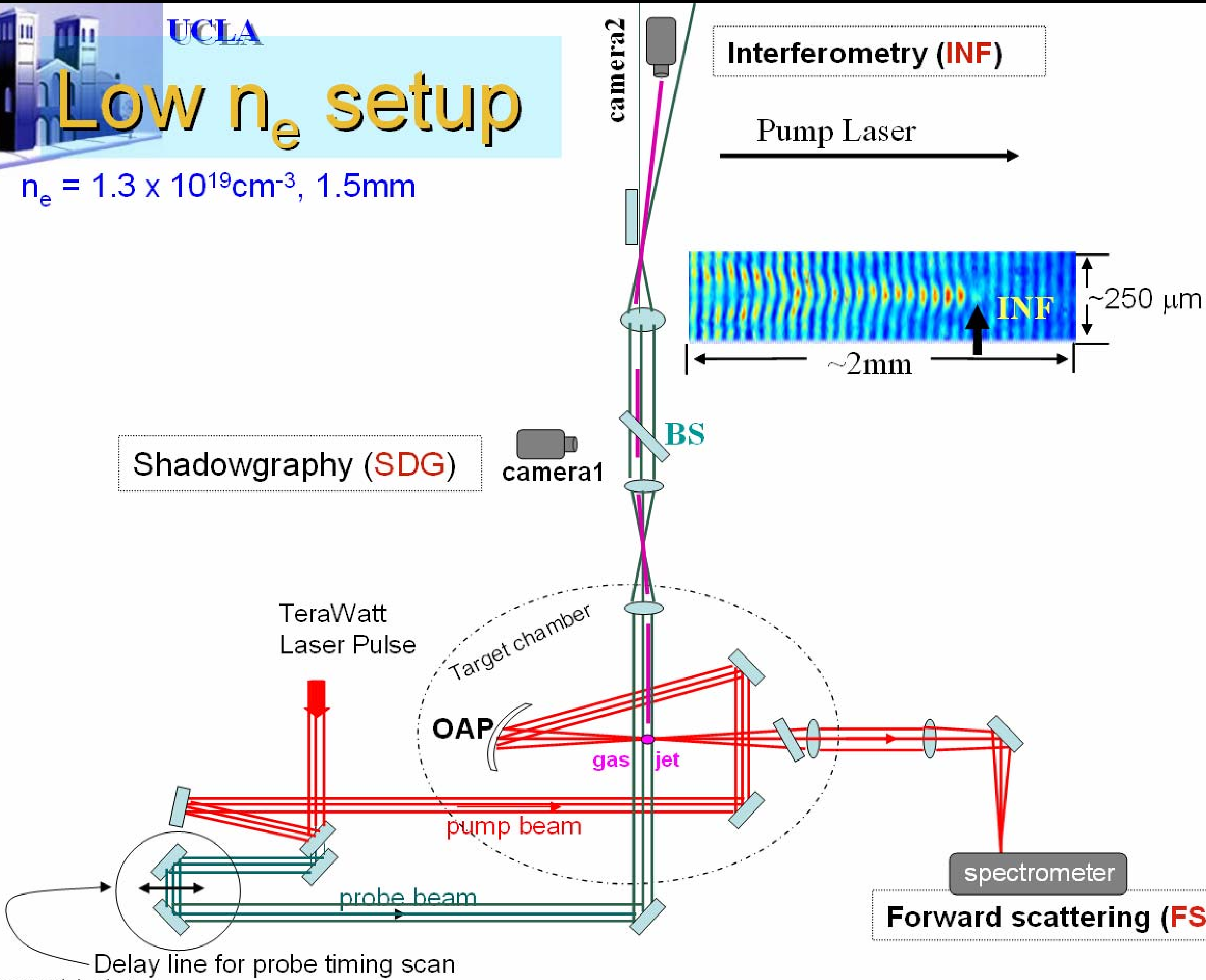

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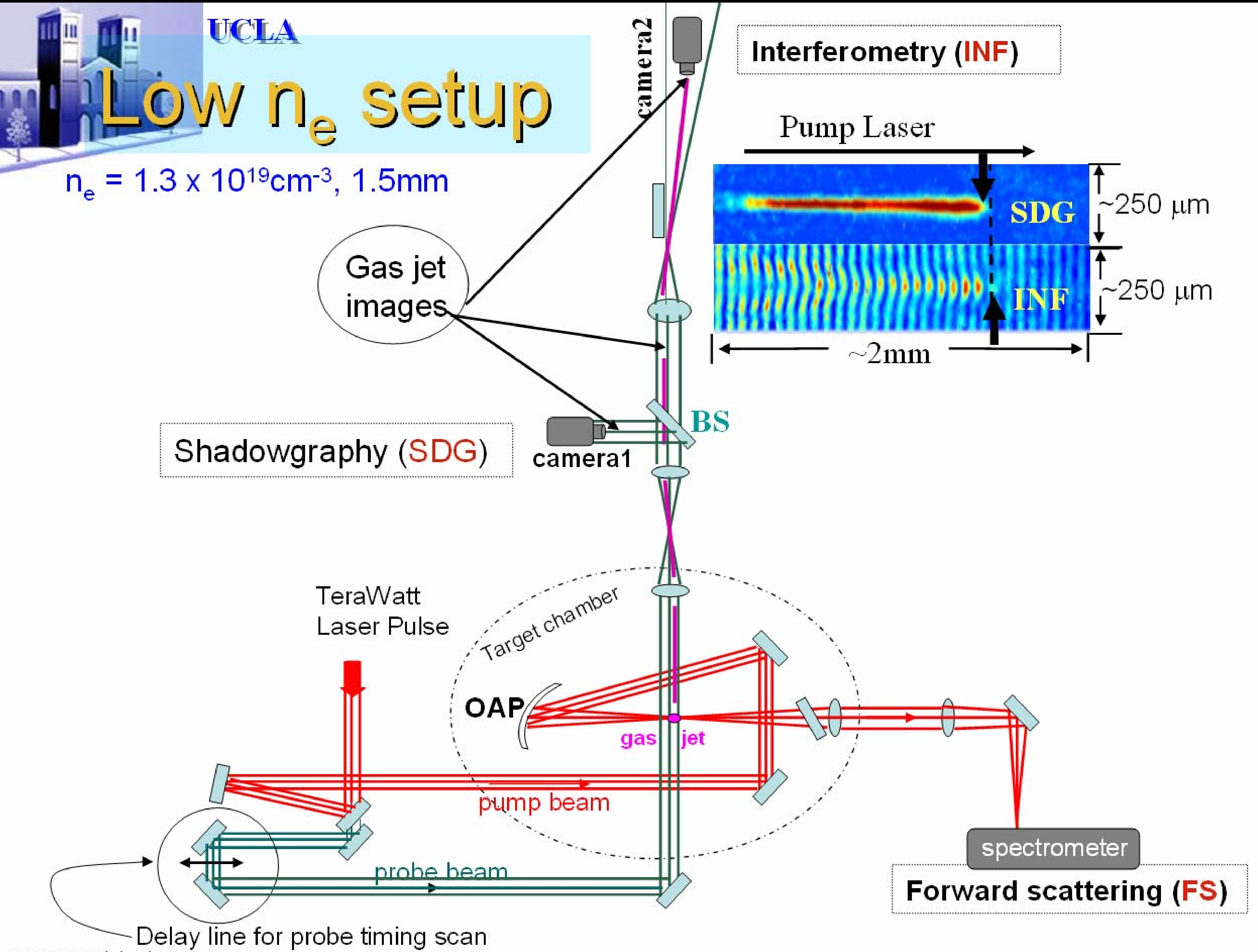

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Low n_e results

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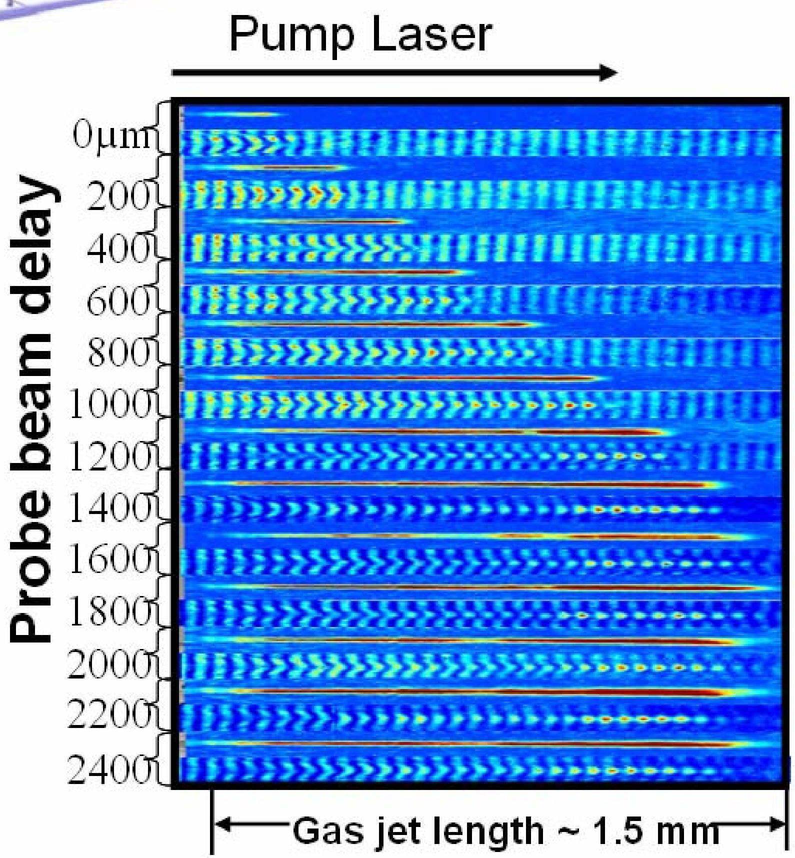

INT & SDG vs delay

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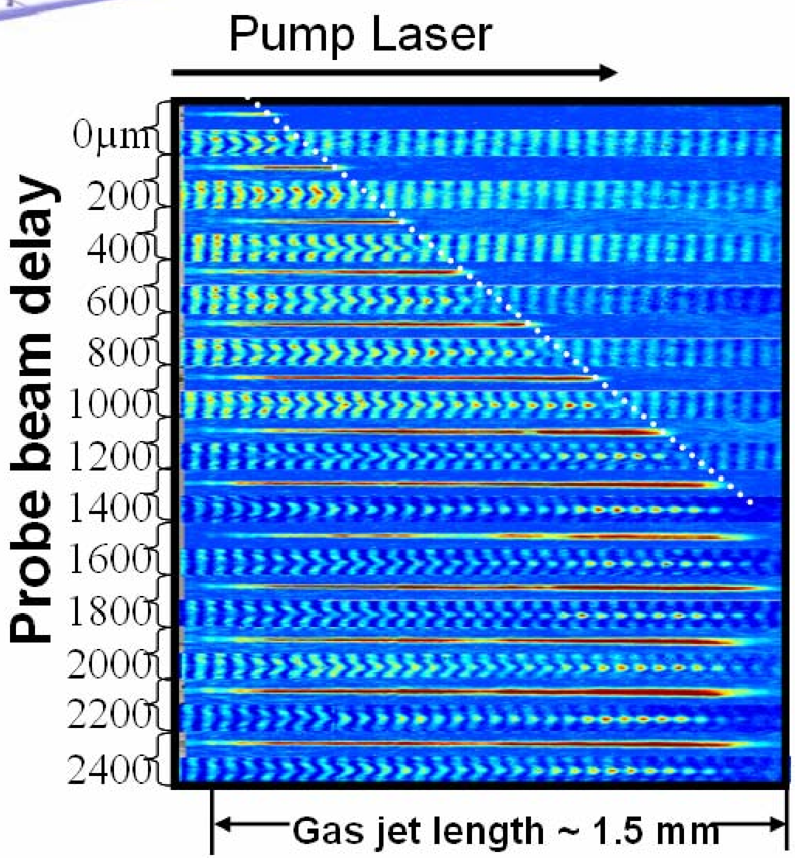

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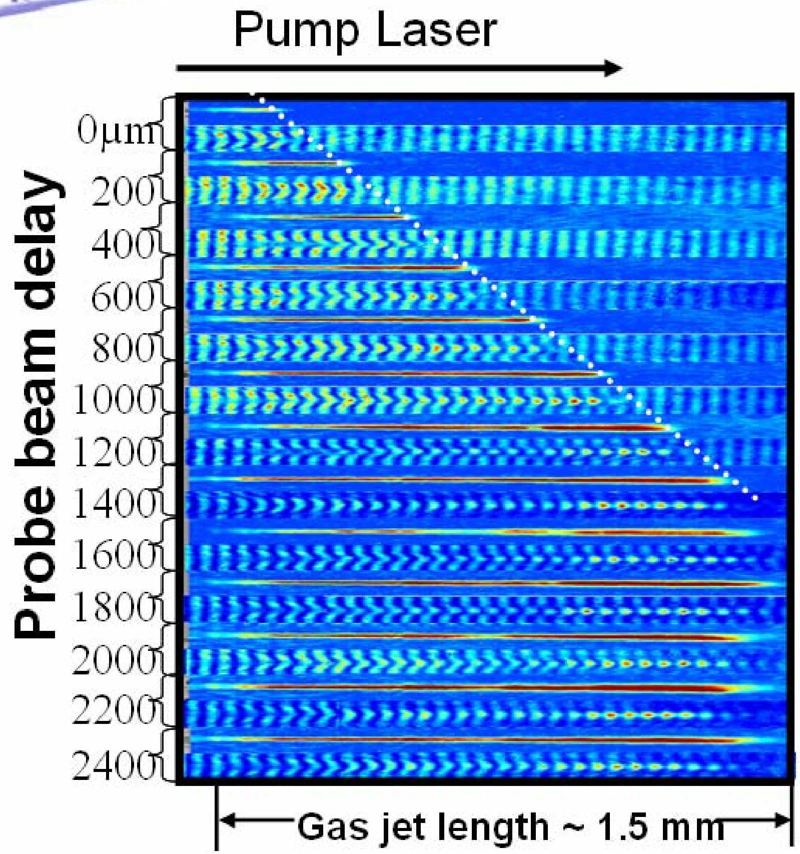

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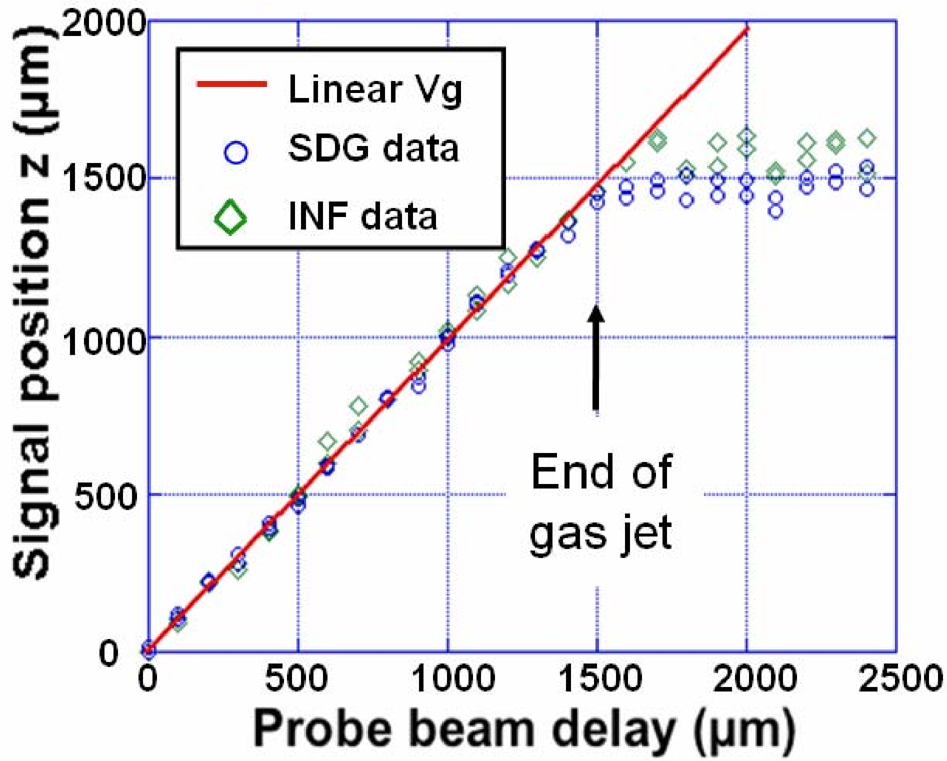

INF & SDG fronts vs delay

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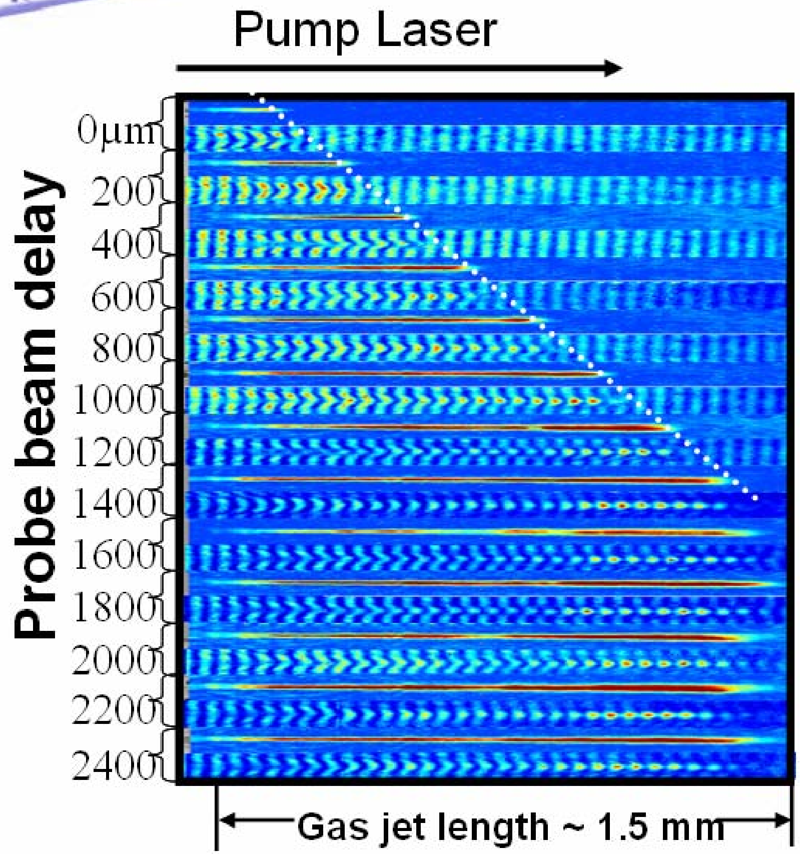

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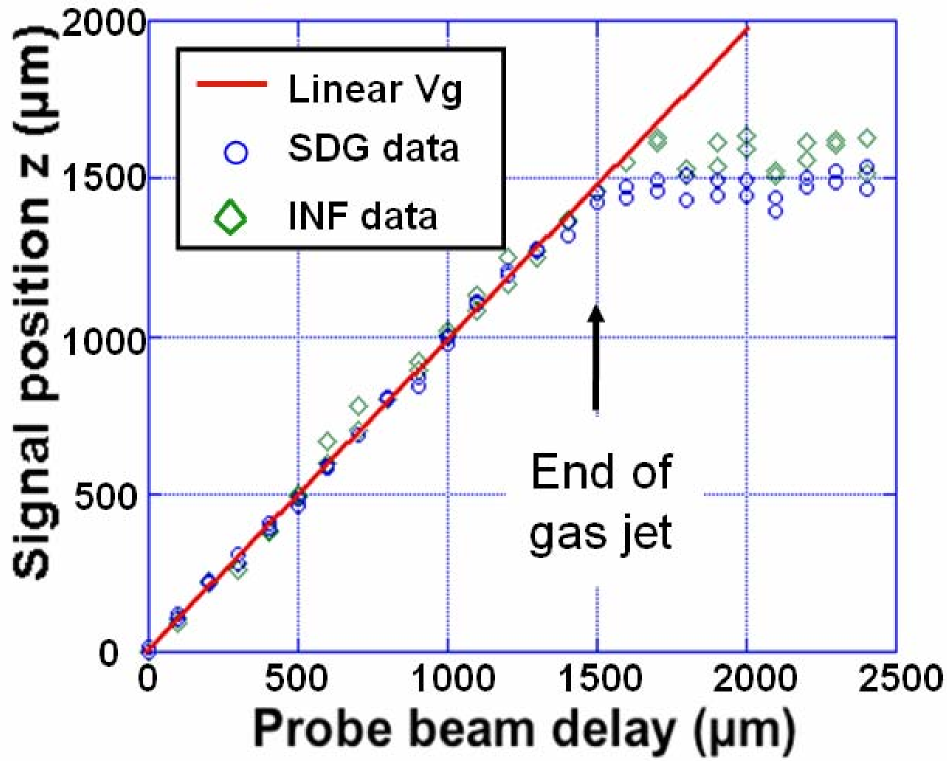

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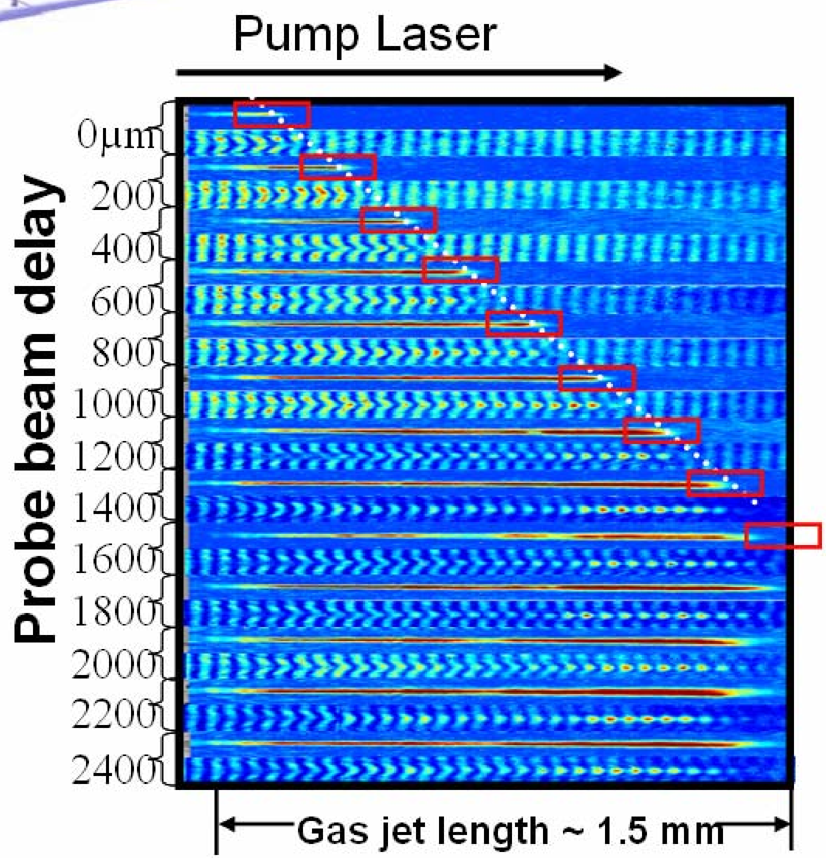

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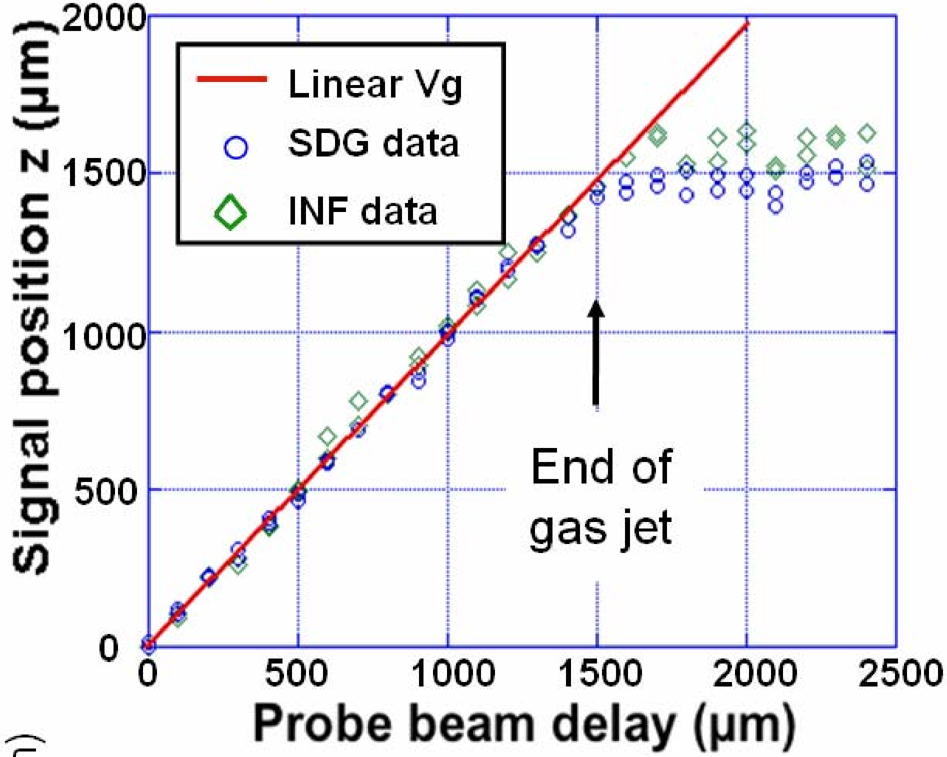
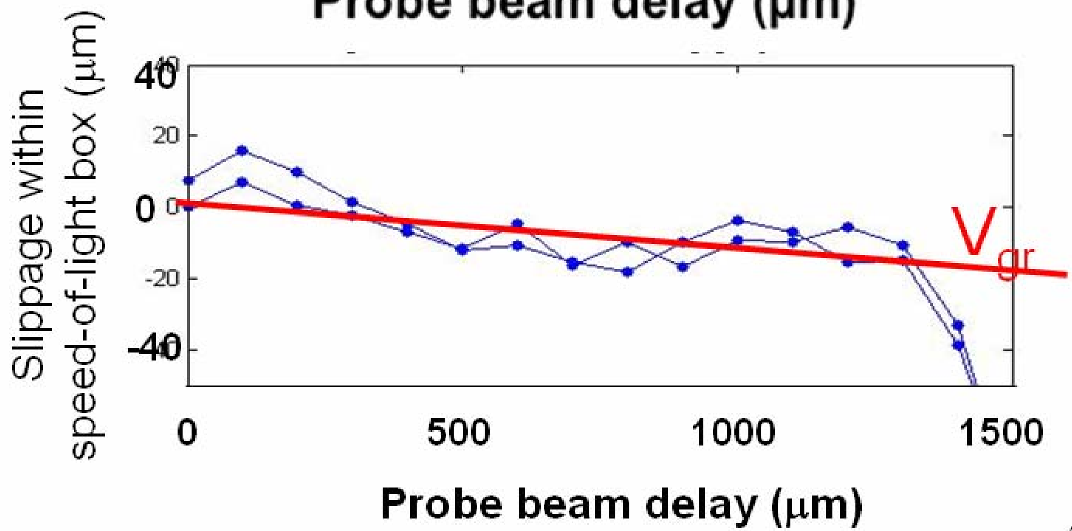
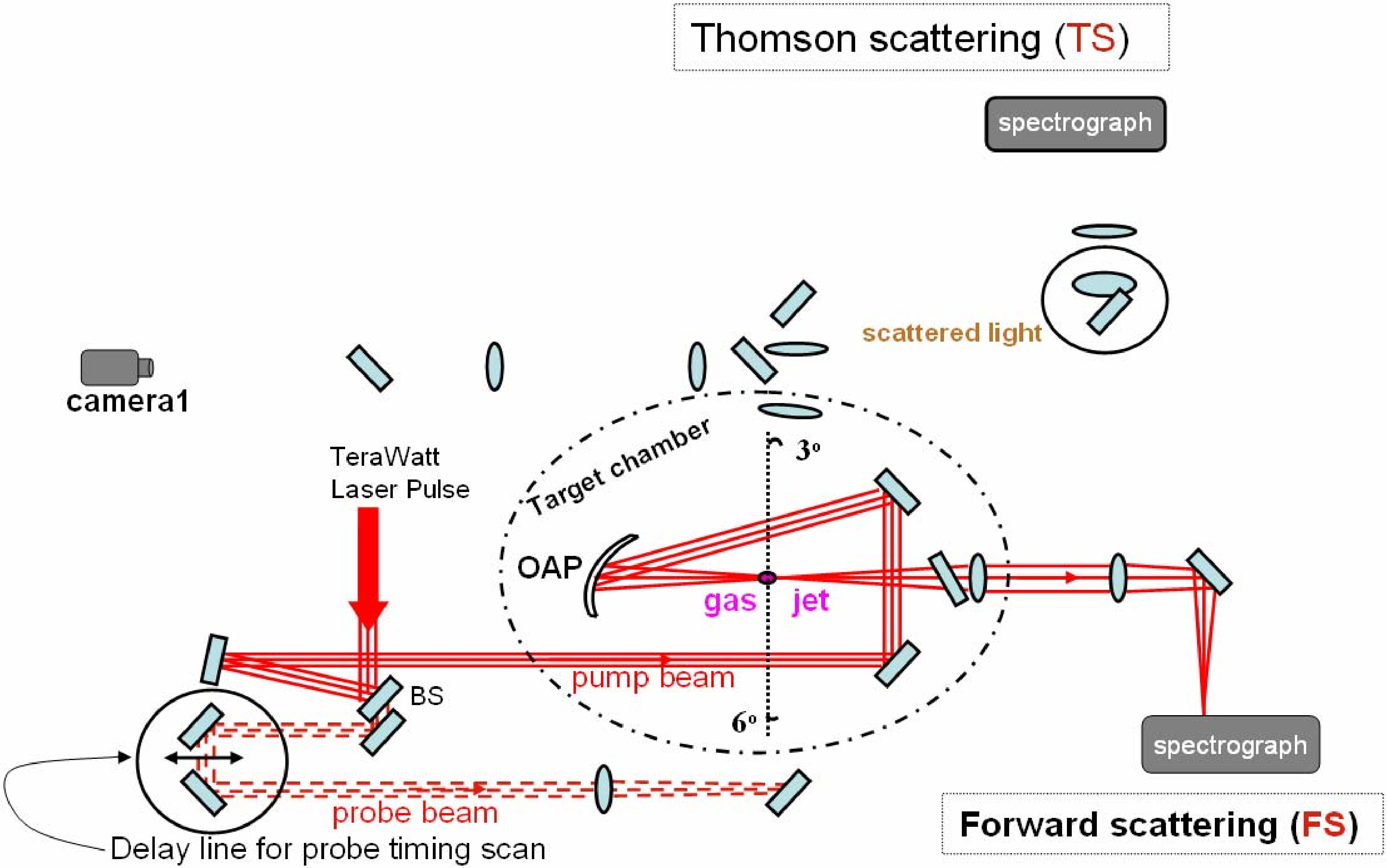




High n_e setup

$n_e = 5 \times 10^{19} cm^{-3}$, 2mm



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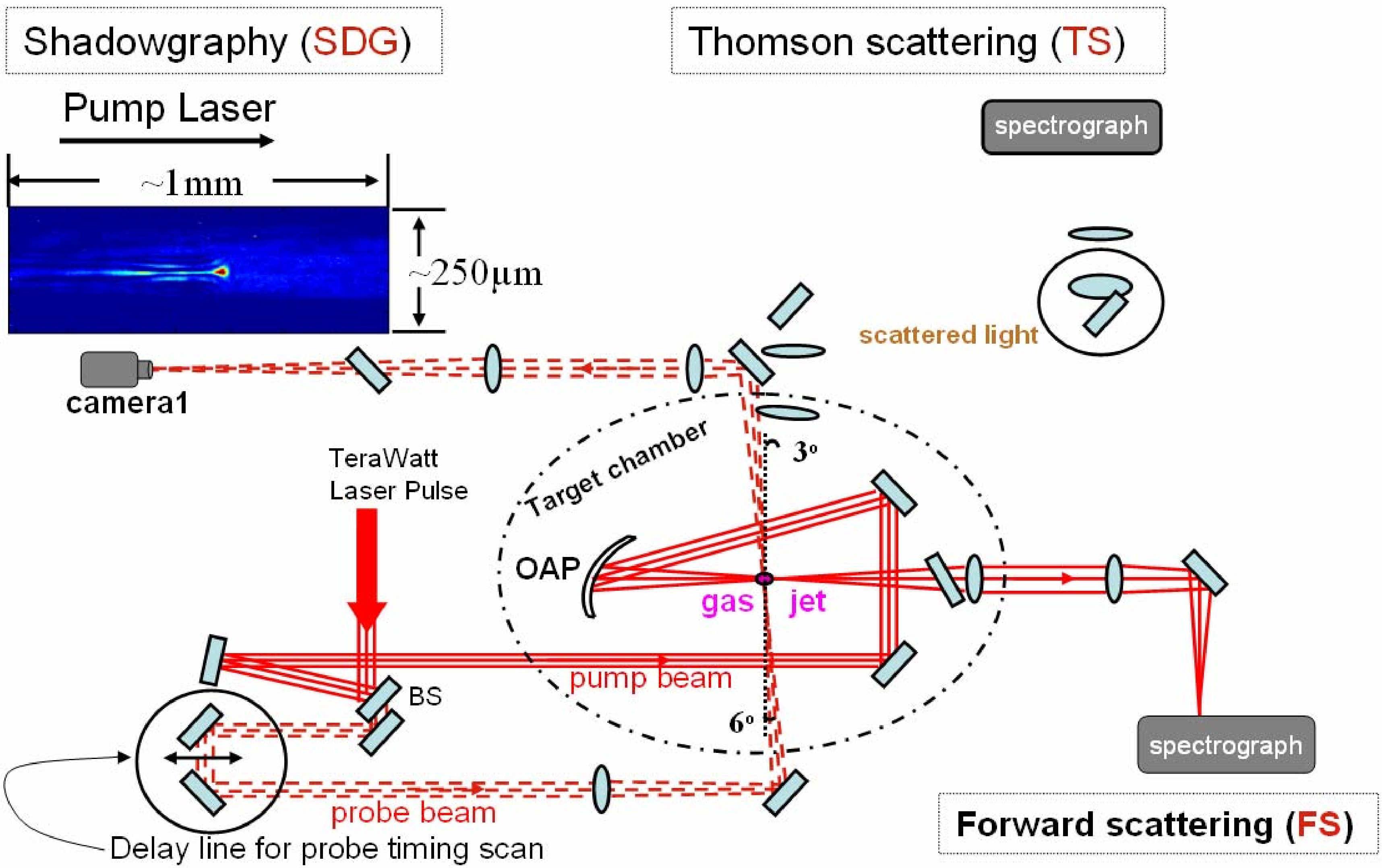

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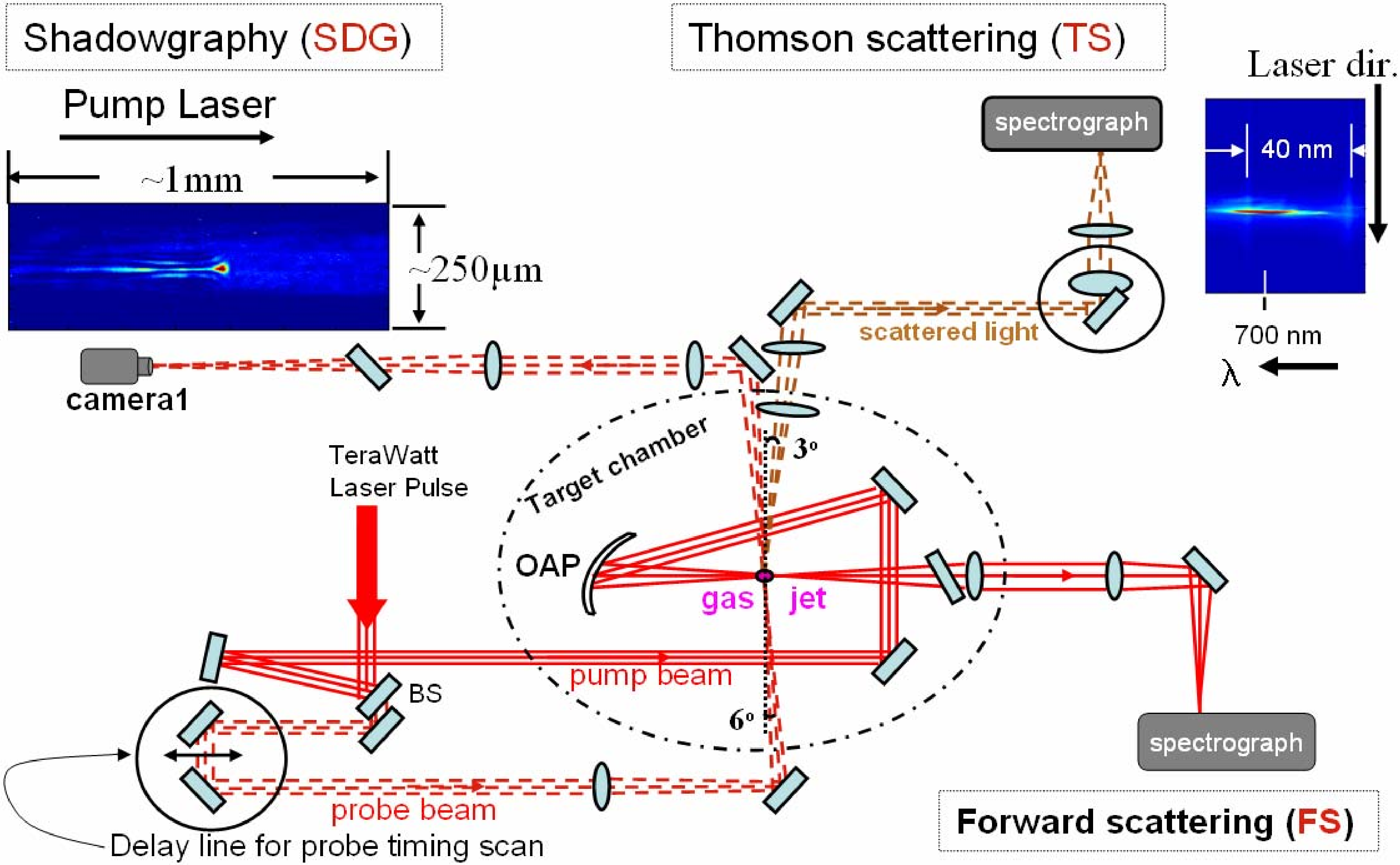

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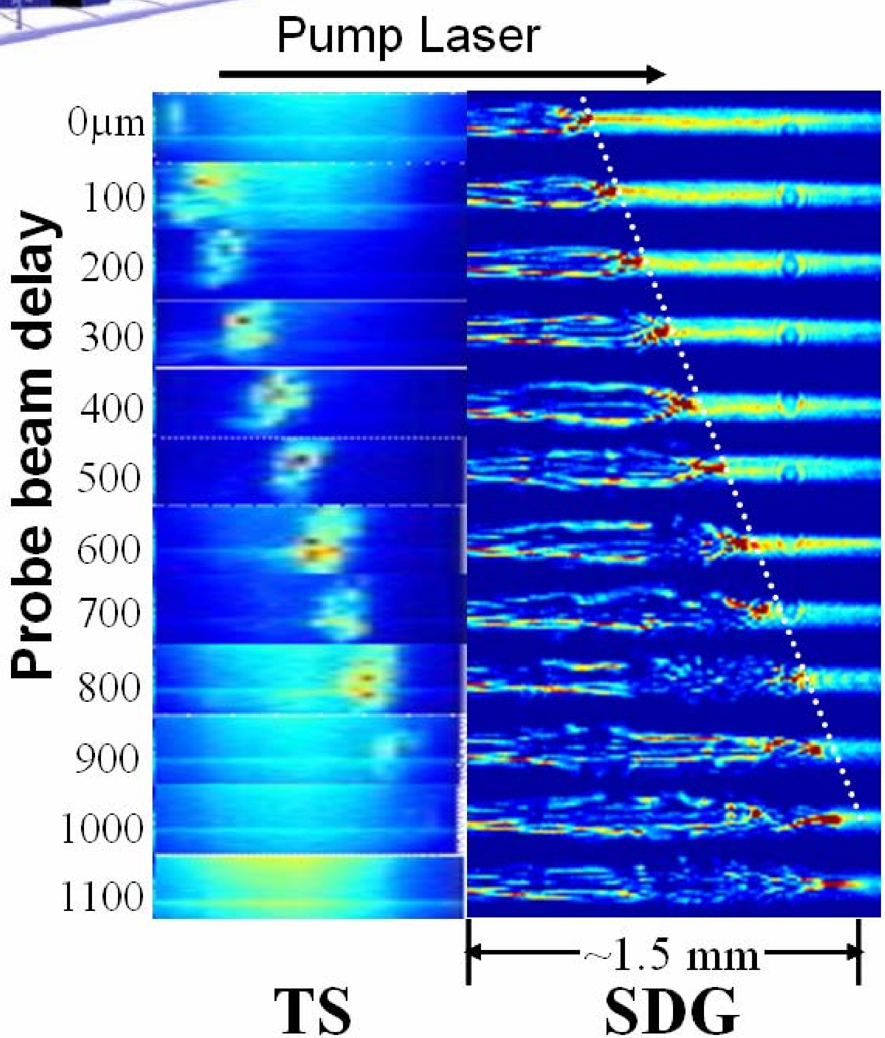
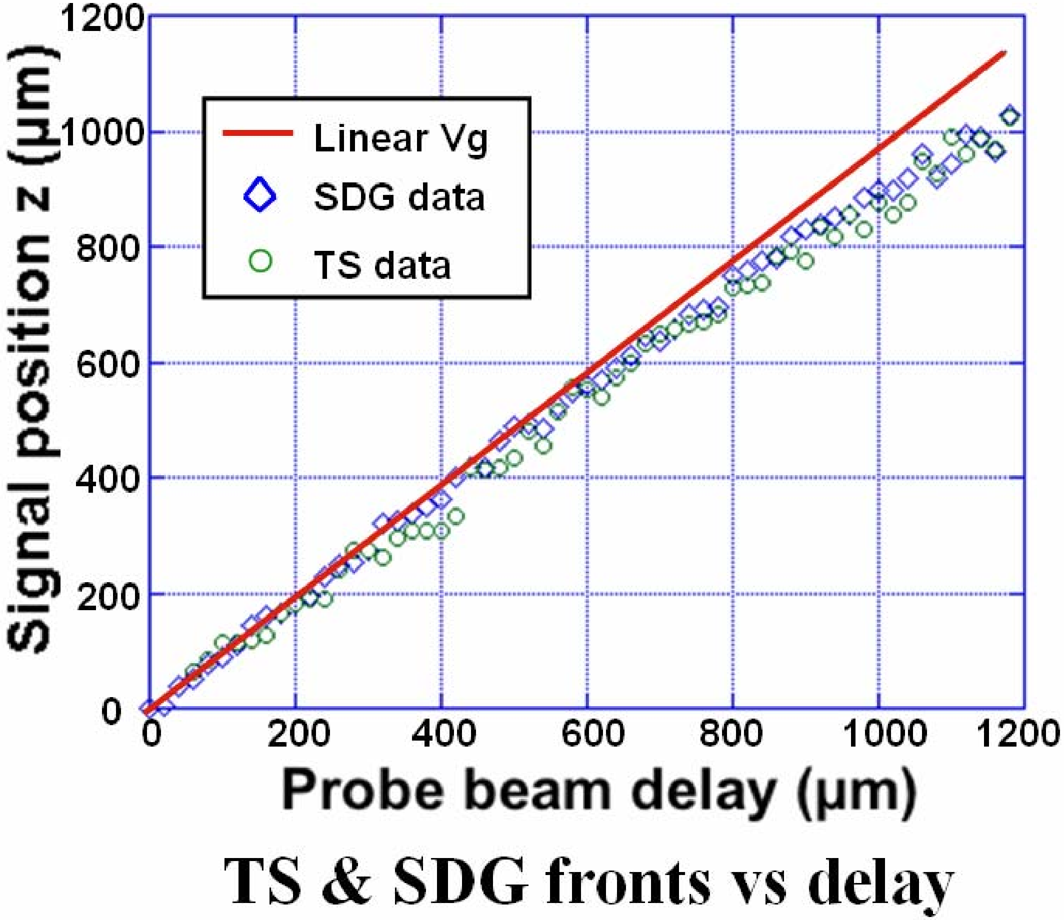




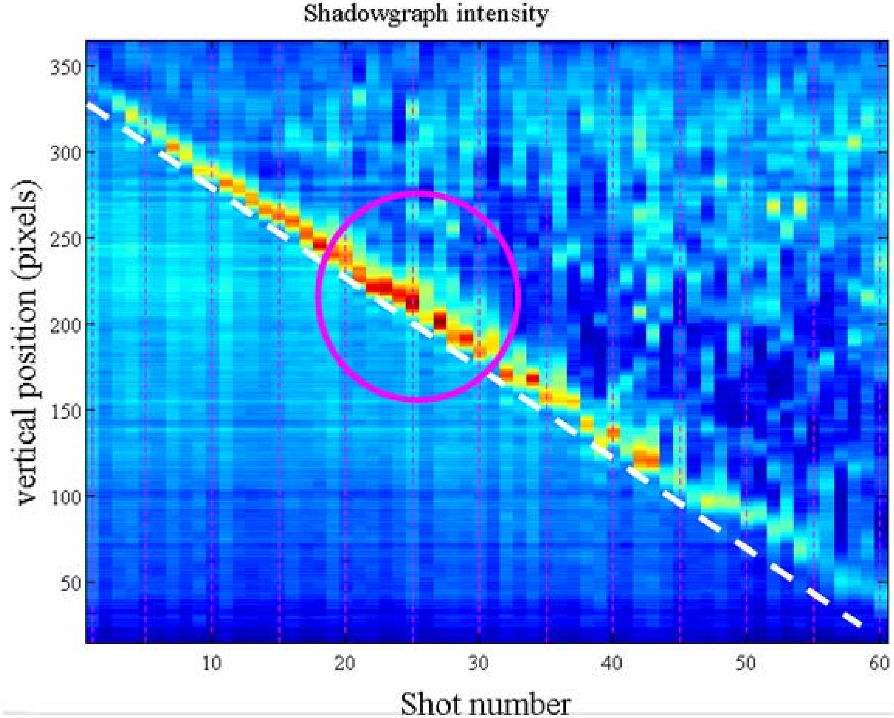
Data points are clearly deviating from linear V_{gr}. But again, moving window shows more detail. But first…

High n_e results (replotted)

$n_e = 5 \times 10^{19} cm^{-3}$, 2mm

Substantial slippage with respect to v_{gr} may be correlated to where EPW amplitude becomes large.

Shadowgraphy (z-resolved).



High n_e results (replotted)

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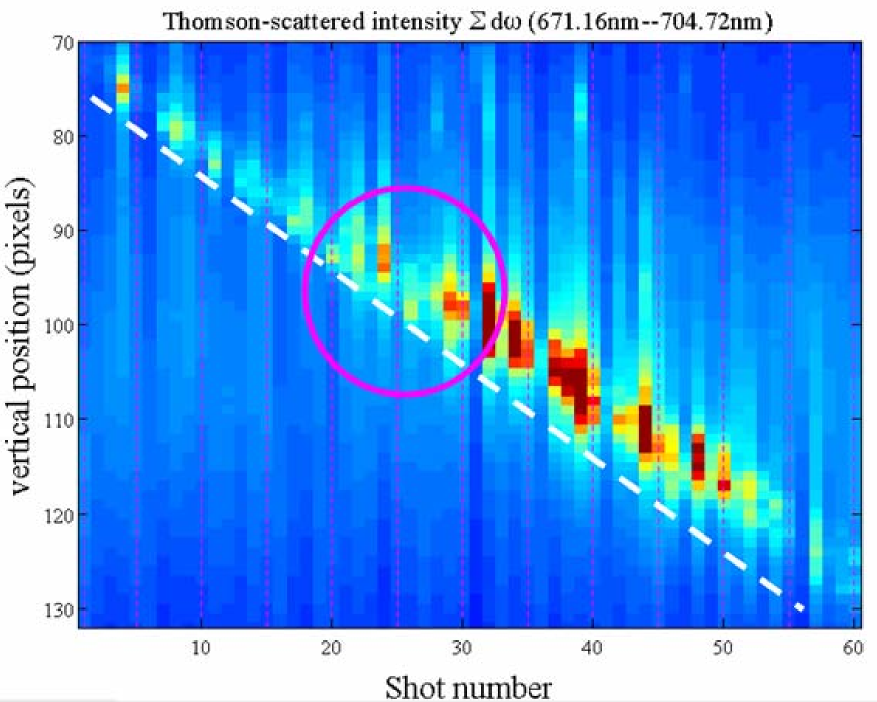
Thomson-scattered intensity (z-resolved)



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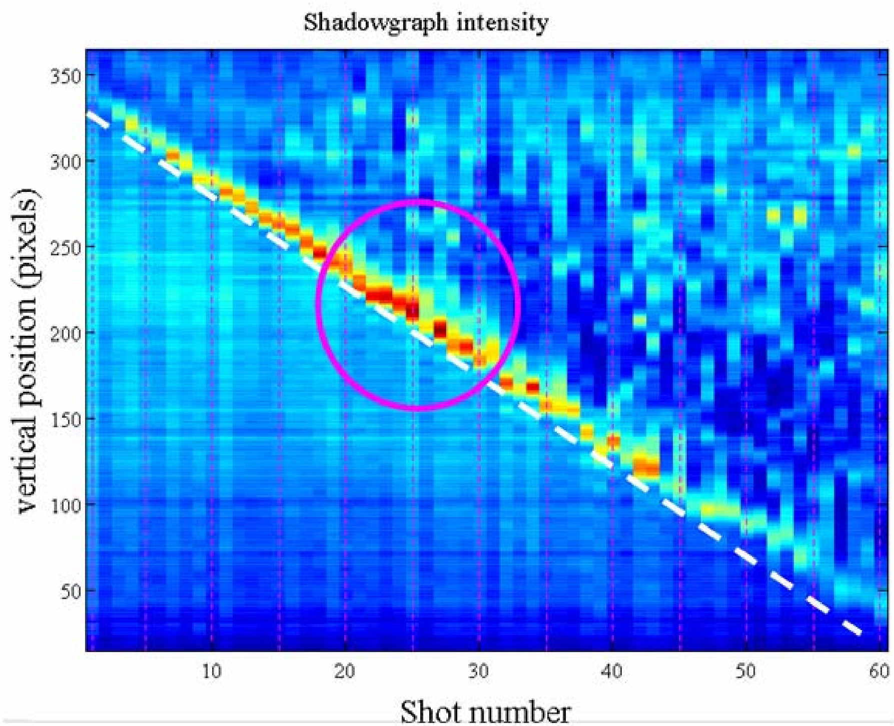
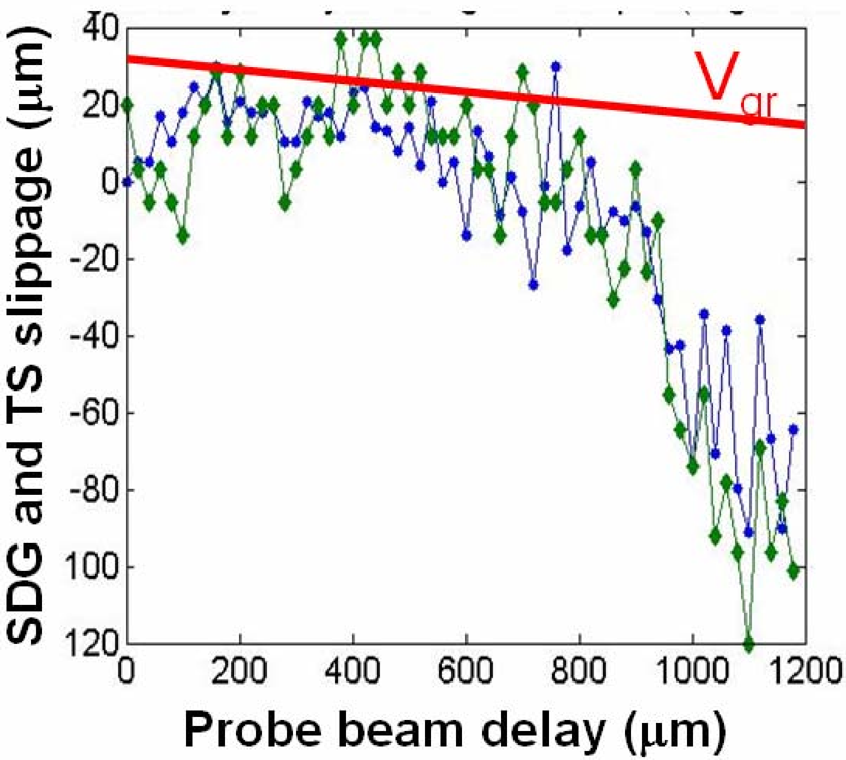
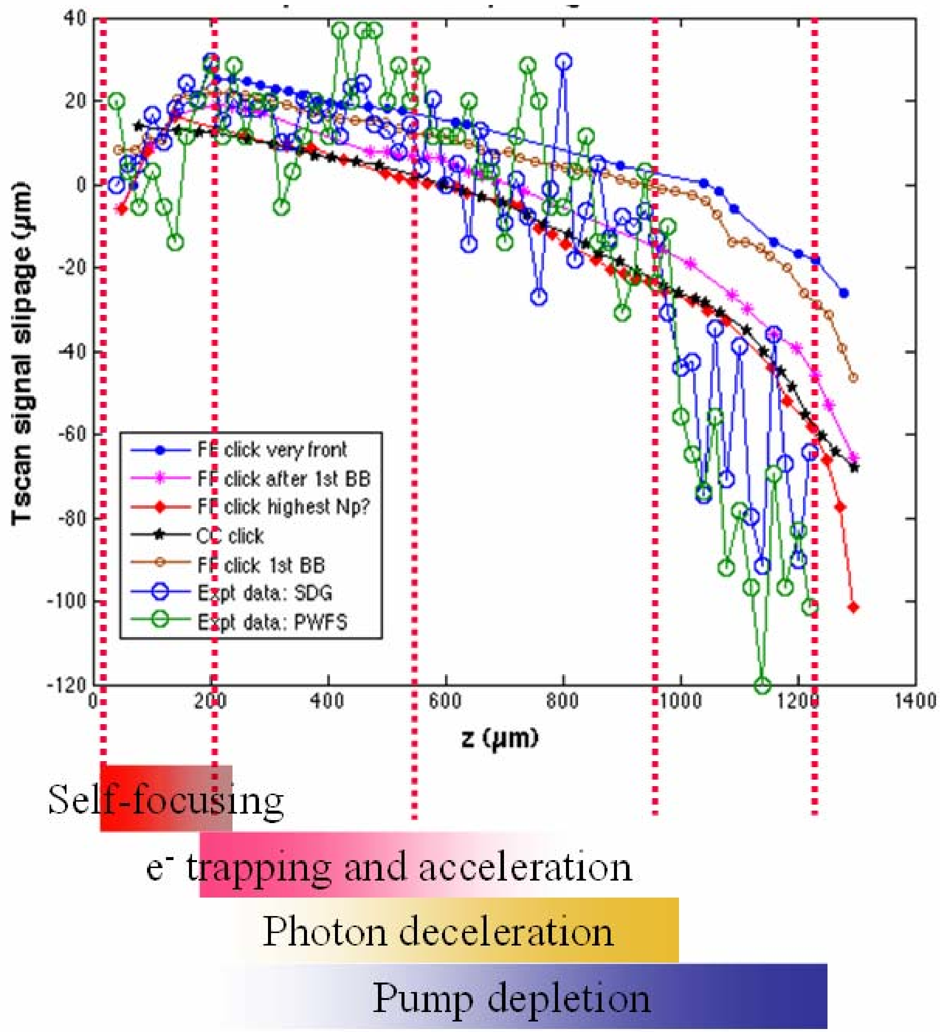


Moving Window Plots for high n_e experiment

$n_e = 5 \times 10^{19} cm^{-3}$, 2mm





Wave-front appears to move 'super-luminal' at first; consistent with self-focusing.

Similar motion of front of wake seen in 3-D simulations of our parameters.

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Conclusions

- We have observed the evolution of the plasma 'wave-front' in a high density ($5 \times 10^{19} cm^{-3}$) plasma.
- Four regions are identified
  - Self-focusing region where the wave-front moves superluminally.
  - A region where the plasma wave is building up.
  - A turning-down of the wave-front velocity from V_{gr}, correlated to the onset of strong Thomson scattering.
  - A final, rapid drop in the wave-front velocity, perhaps associated with pump depletion.
- The integrated slippage of the wave-front at Z=800μm is $\sim 8\ \lambda_p$ and therefore must have a major impact on electron dephasing.