ATF Plasma Sources for Wakefield Electron Acceleration

Daniil Stolyarov, Marcus Babzien, Igor Pavlishin, Karl Kusche, Igor Pogorelsky, Wayne Kimura, Patric Muggli, Efthymios Kallos, Vitaly Yakimenko

ATF User's Meeting
Brookhaven National Laboratory
April 4-6, 2007

Plasma Density Requirements for Plasma Acceleration Experiments at ATF

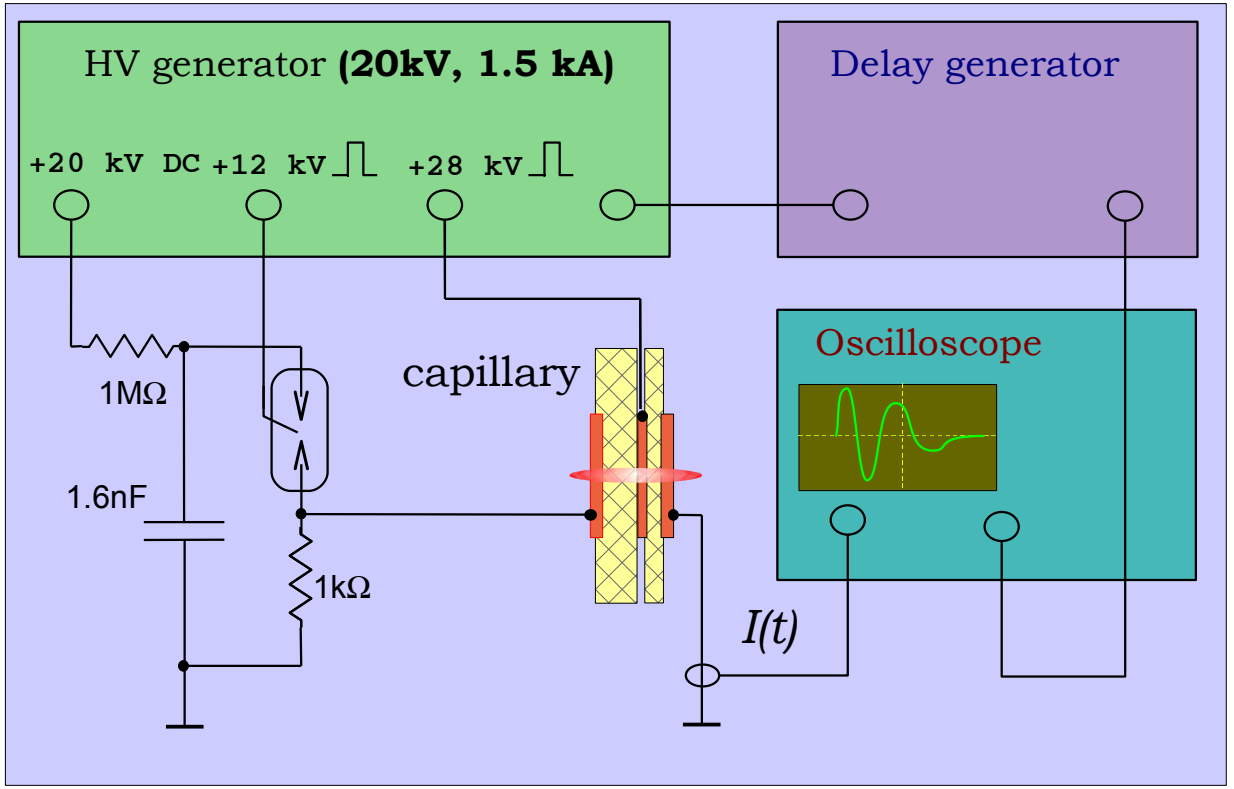
$$\omega_p = \sqrt{\frac{4\pi n_e e^2}{m_e}}.$$ Plasma frequency

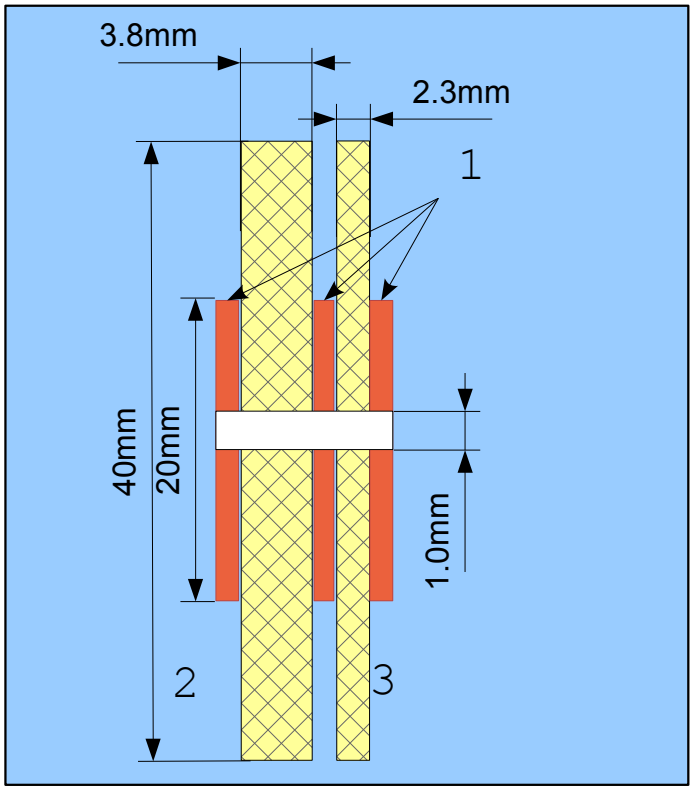
Experiment	*Plasma Density*
Multibunch Resonant PWFA (P. Muggly, et. al.)	$4 \cdot 10^{19}$ cm^{-3}
STELLA-LW (Wayne Kimura, et. al)	10^{16}-10^{17} cm^{-3}

Plasma Sources at ATF

- Ablative discharge capillary
- Gas-filled capillary
- Gas jet

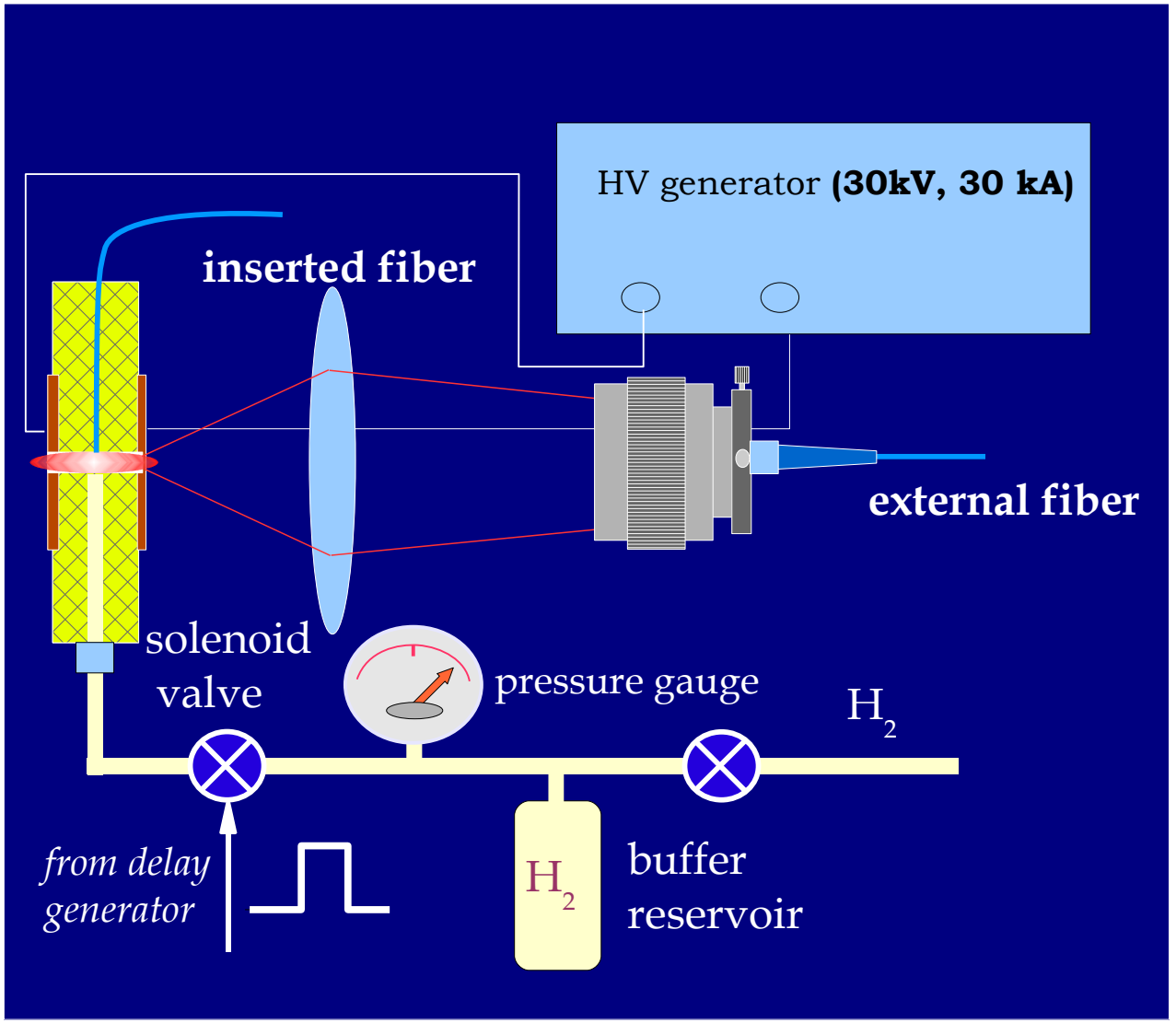
Plasma Sources: Ablative discharge capillary

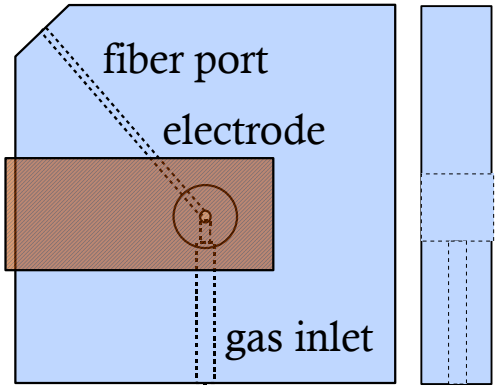




- Ablative capillary can produce plasma with densities: $10^{14} – 10^{17}$ cm^{-3}
- The plasma is “made” out of material ablated from the walls of the capillary
- Capillary lifetime is limited

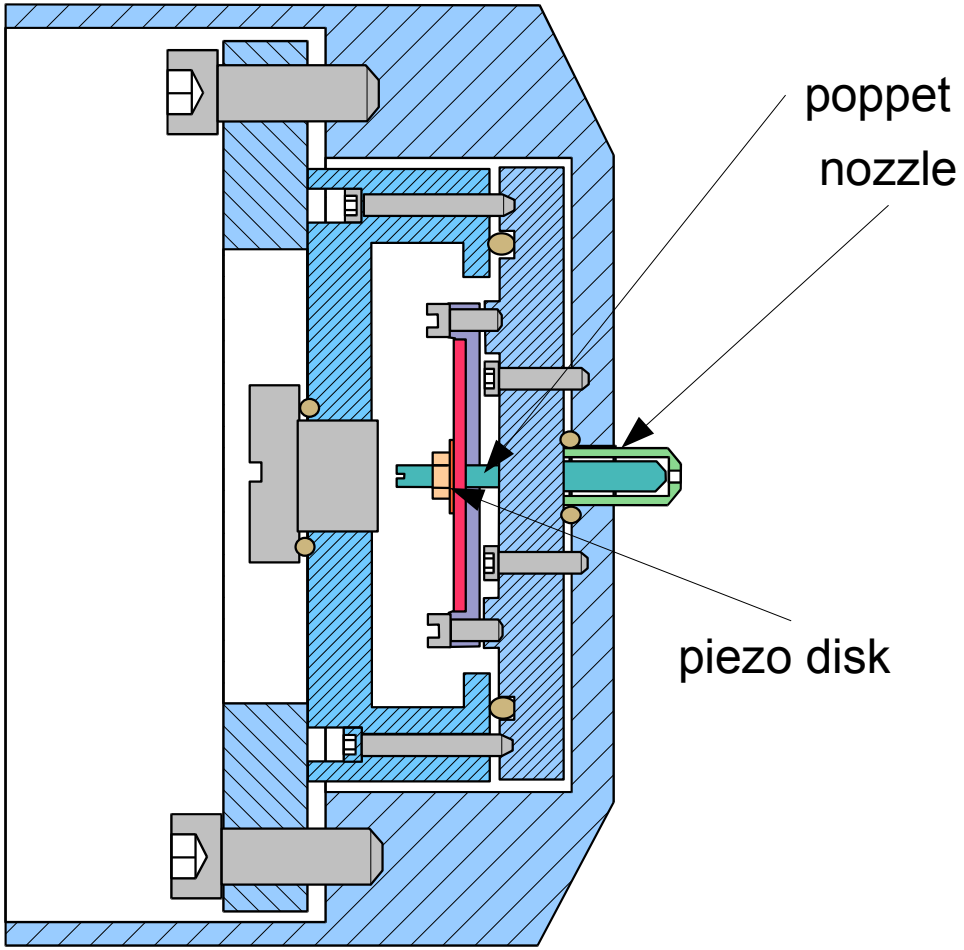
Plasma Sources: gas-filled discharge capillary





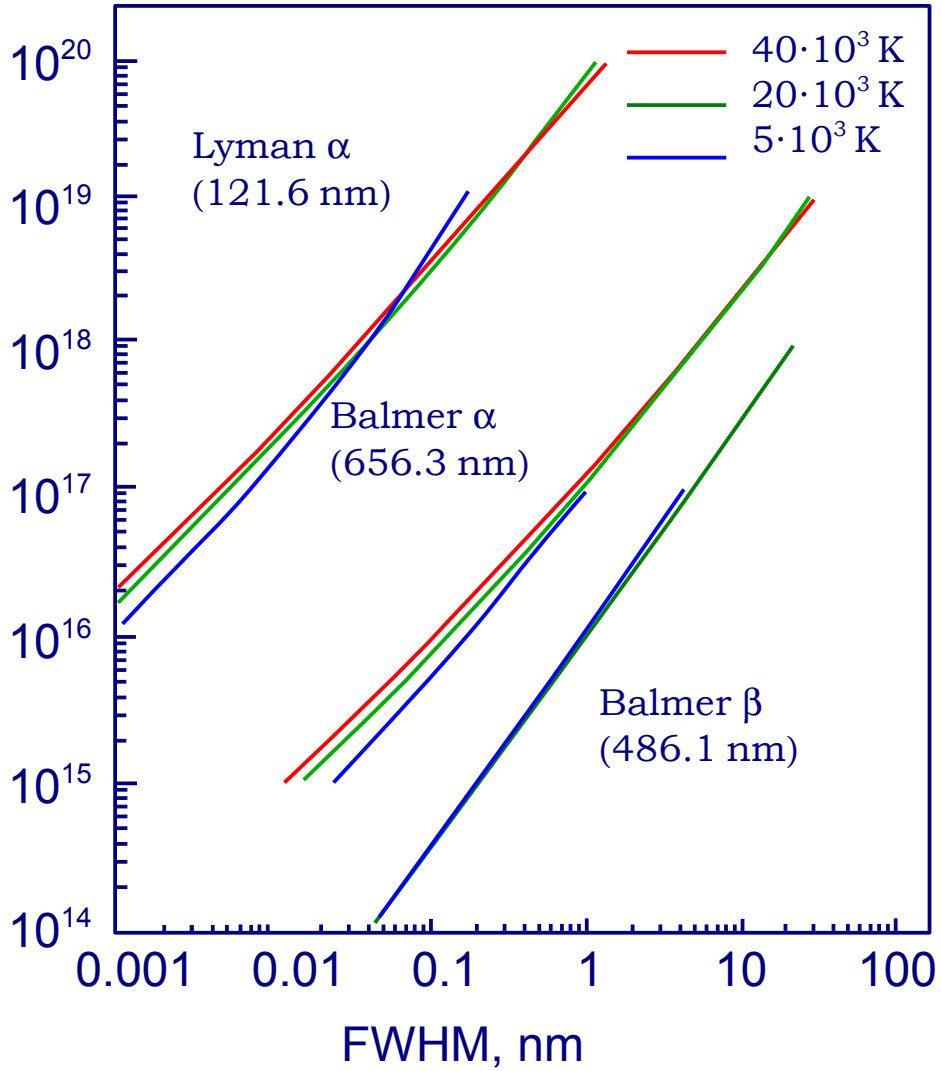
- Plasma concentration: 10^{15} – 10^{18} cm^{-3}
- Additional density control
- Wide range of available plasma densities
- Simple electrical scheme
- Clean plasma

Plasma Sources: Gas Jet



- Gas concentration : $4 \cdot 10^{19} cm^{-3}$ (at back pressure:10 psi, 30 μs gate)
- Gas jet can be used for LWFA or as a target for ion generation experiment

Diagnostics: Stark broadening of atomic hydrogen lines



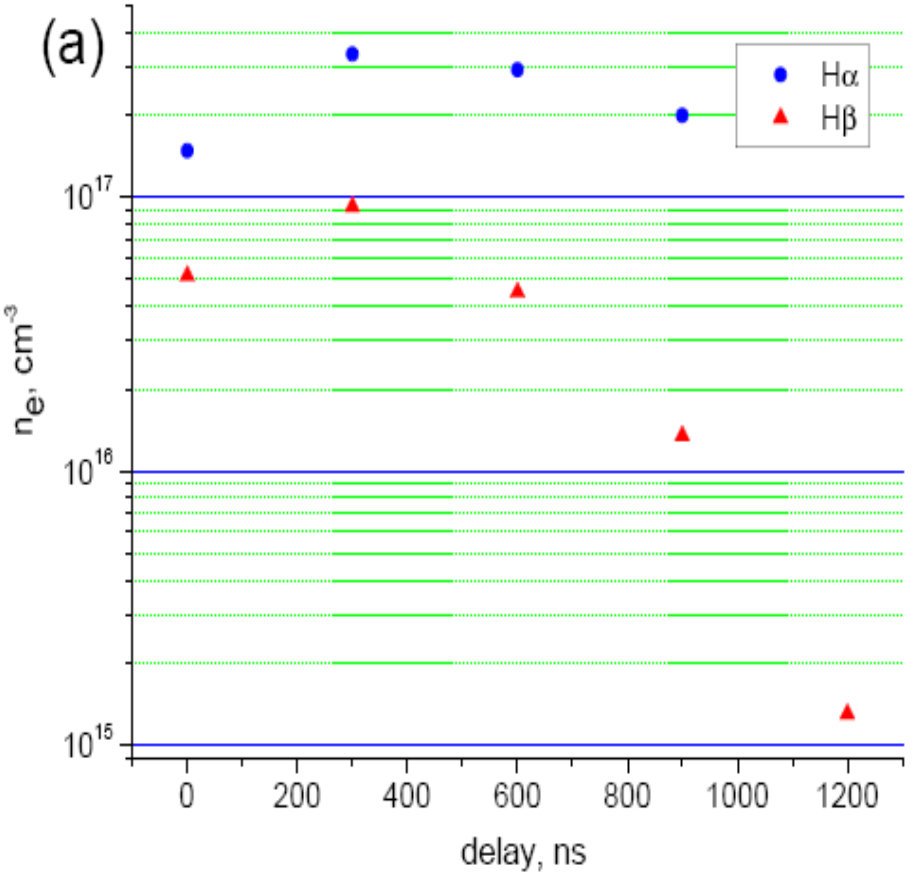
- $N_e = C(N_e, T) \cdot \Delta\lambda^{3/2}$

where $C(N_e, T)$ is a week function of N_e and T.

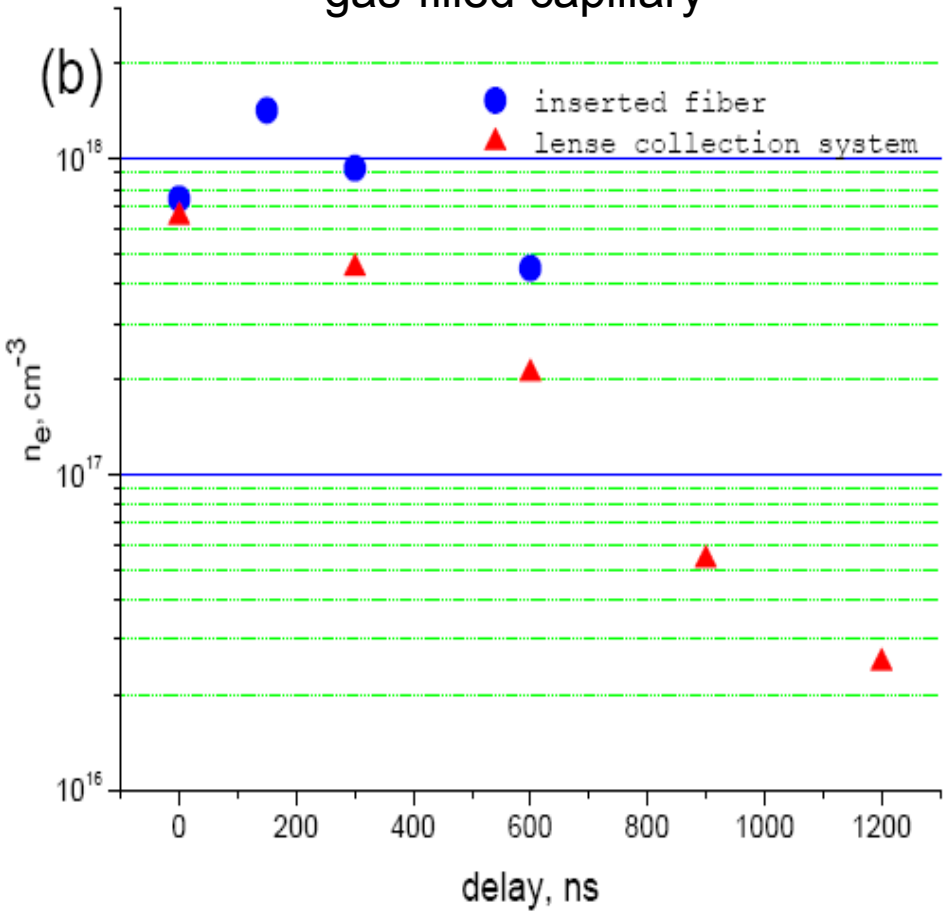
- If the electron temperature is known the accuracy of the plasma density measurements can be 10-20%
- Balmer α (656.3 nm) and Balmer β (486.11nm) are most convenient for observation hydrogen lines

Dependence of plasma density upon time delay

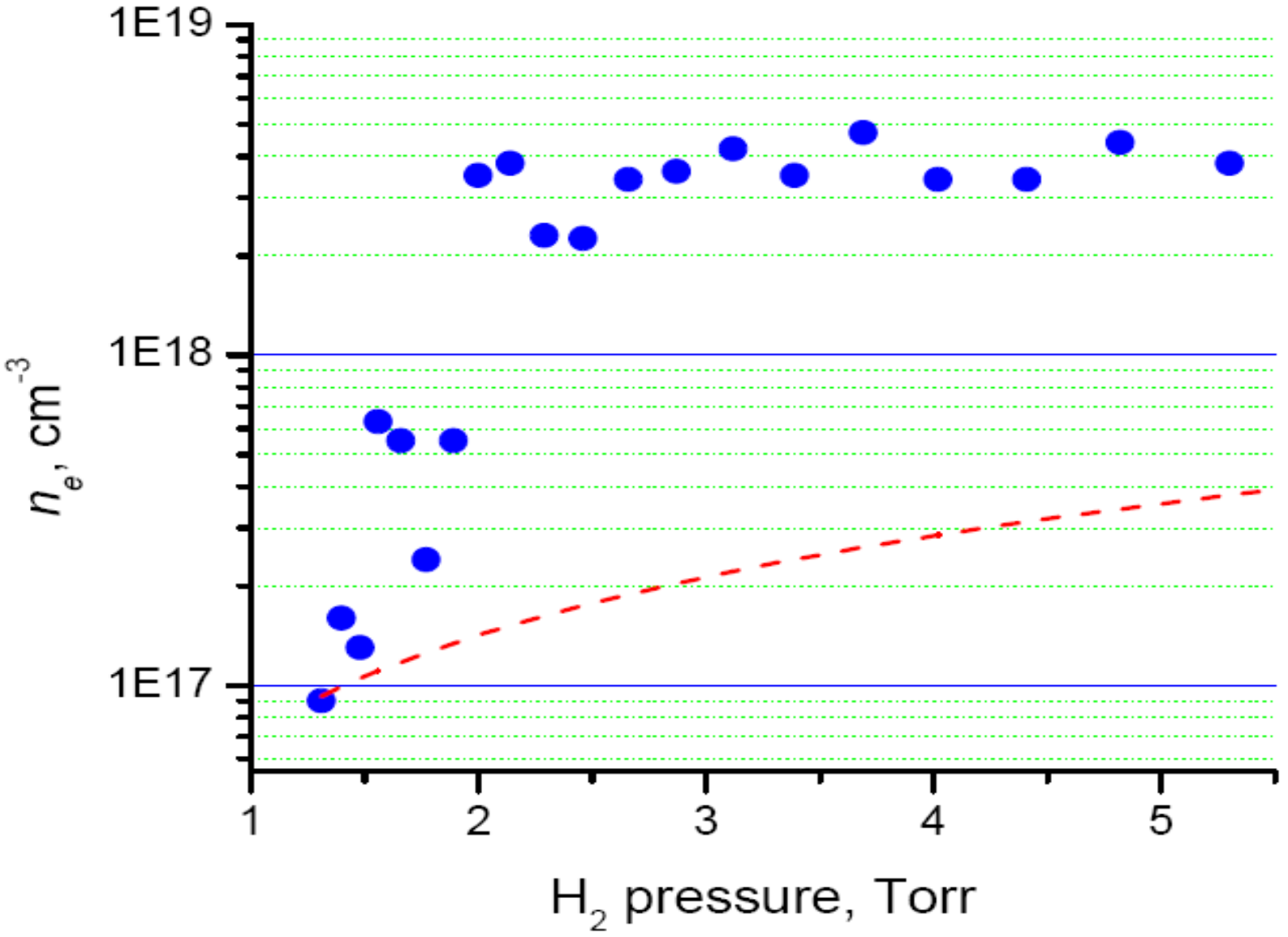
ablative capillary



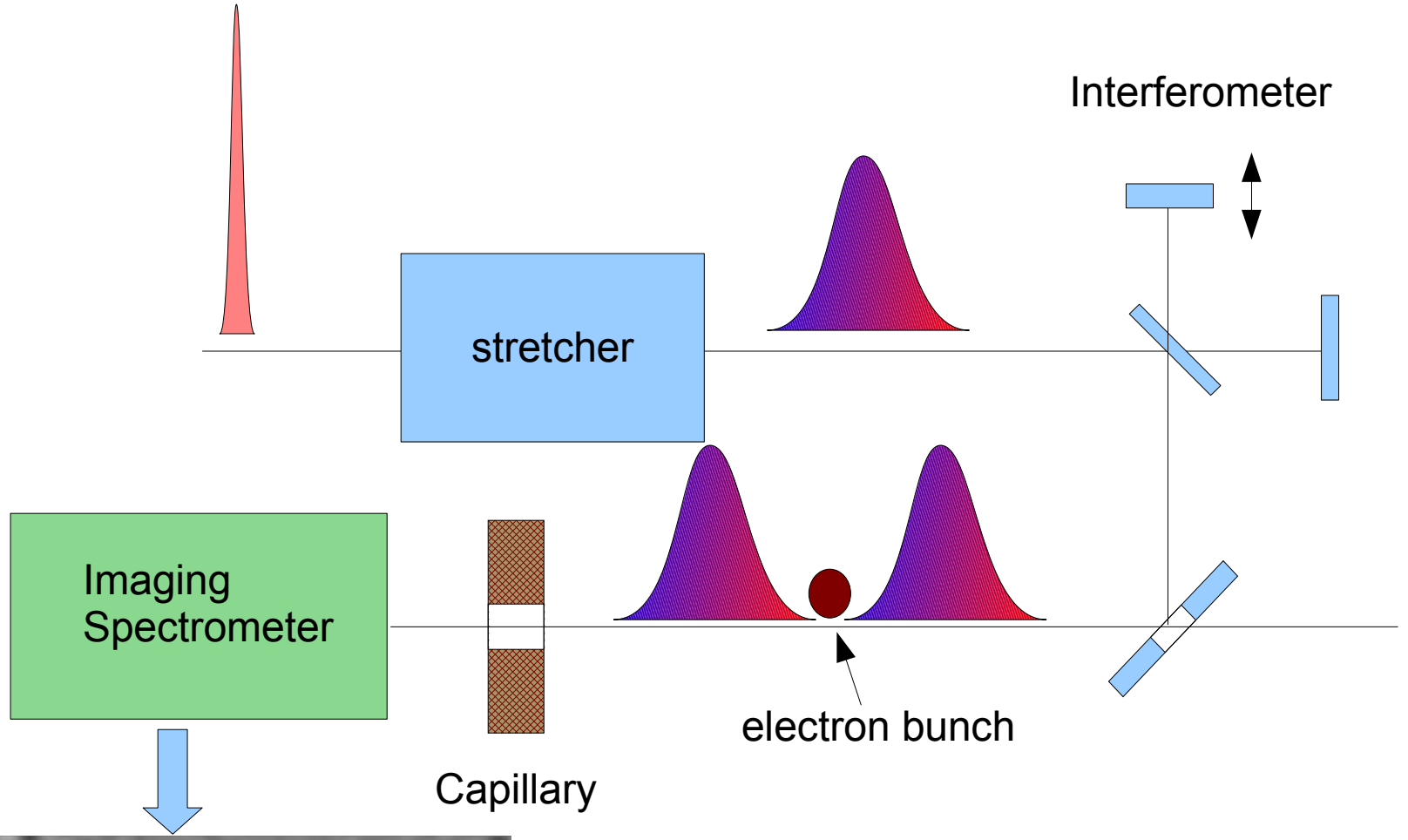
gas-filled capillary

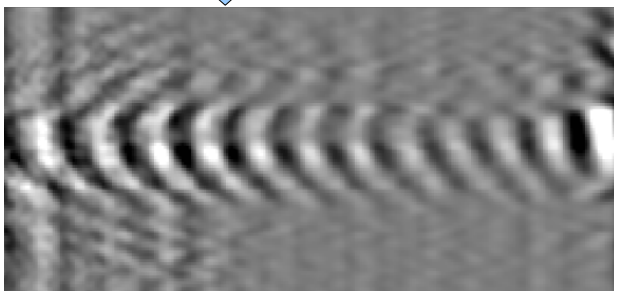


Dependence of the plasma density upon pressure (hybrid capillary)



Frequency Domain Holography





(N. H Maltis et. al. Proceedings AAC06)

Frequency domain holography allows to detect transient changes in plasma density

Summary

- Plasma sources:
  - Ablative capillary; (10^{15}-10^{17} cm^{-3})
  - Gas-filled capillary;(10^{16}-10^{18} cm^{-3})
  - Gas jet (0..>10^{19} cm^{-3})
- Plasma Diagnostics:
  - Stark Broadening Measurements
  - Frequency Domain Holography (to be implemented)