

Diagnósticos Óptico-Refractivos en Ondas de Choque: *Aplicaciones en Física de Plasmas*

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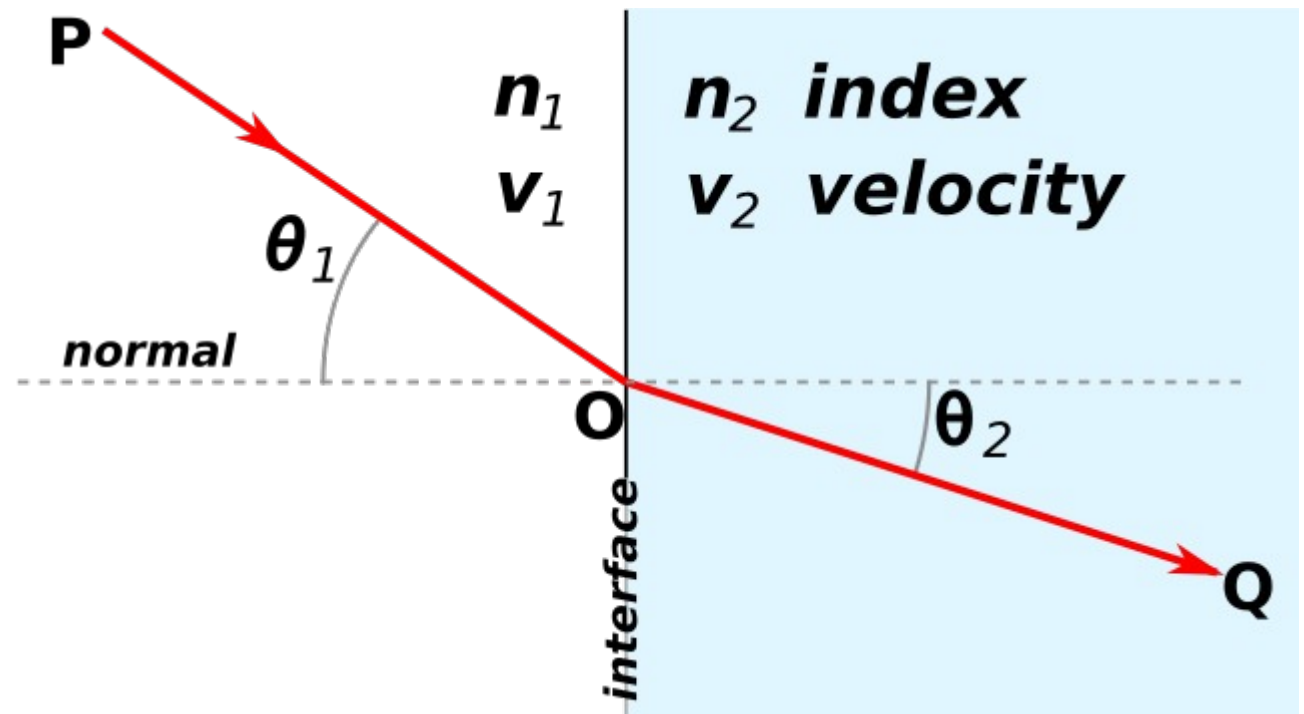
Center for Research and Applications in Plasma Physics and Pulsed Power, P⁴, Chile



Indice de refracción

$$n = \frac{c}{v}$$

$$n_1 \operatorname{sen}(\theta_1) = n_2 \operatorname{sen}(\theta_2)$$



Ley de Snell

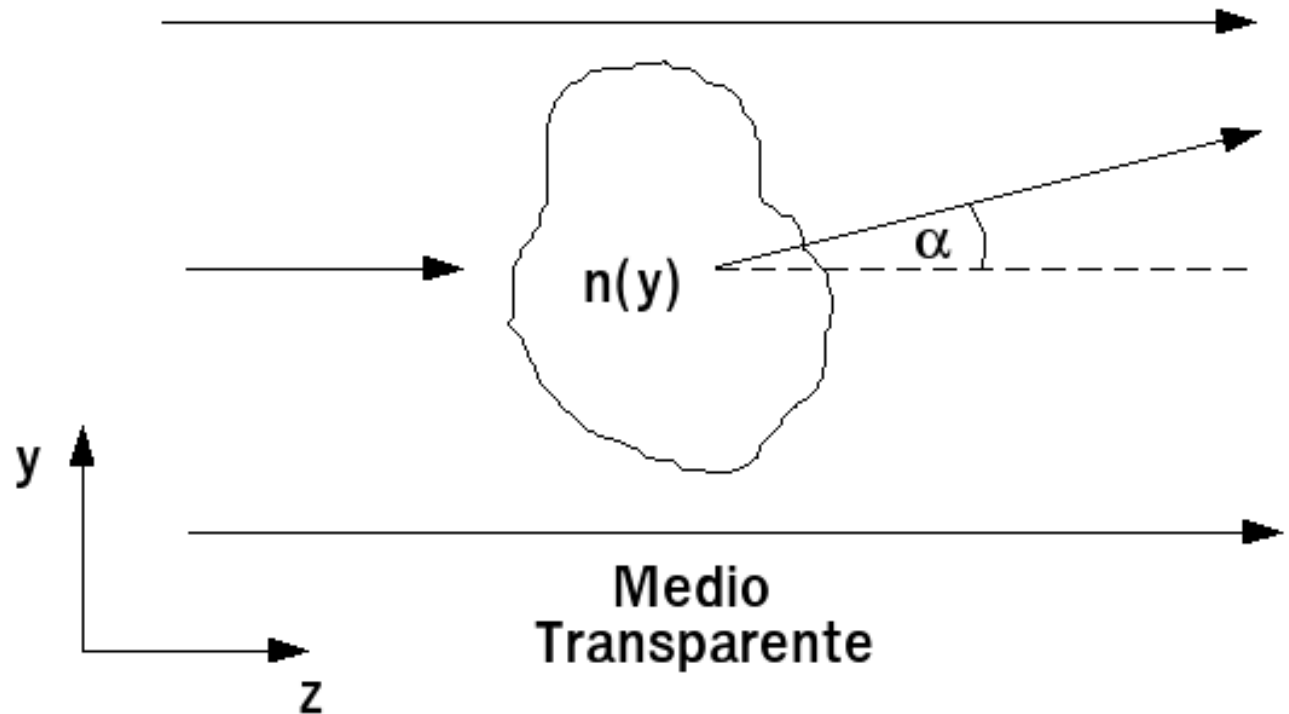




Permiten el estudio de las distribuciones de gradientes de densidad en medios transparentes:

- Schlieren
- Shadow
- Interferometría

$$\alpha = \frac{\lambda}{n_a} \int \frac{\partial n}{\partial y} dz$$



*Basado en el Capítulo 11, "Fluid Mechanics Measurements", R J Goldstein, Hemisphere Publishing Corporation, 1983.

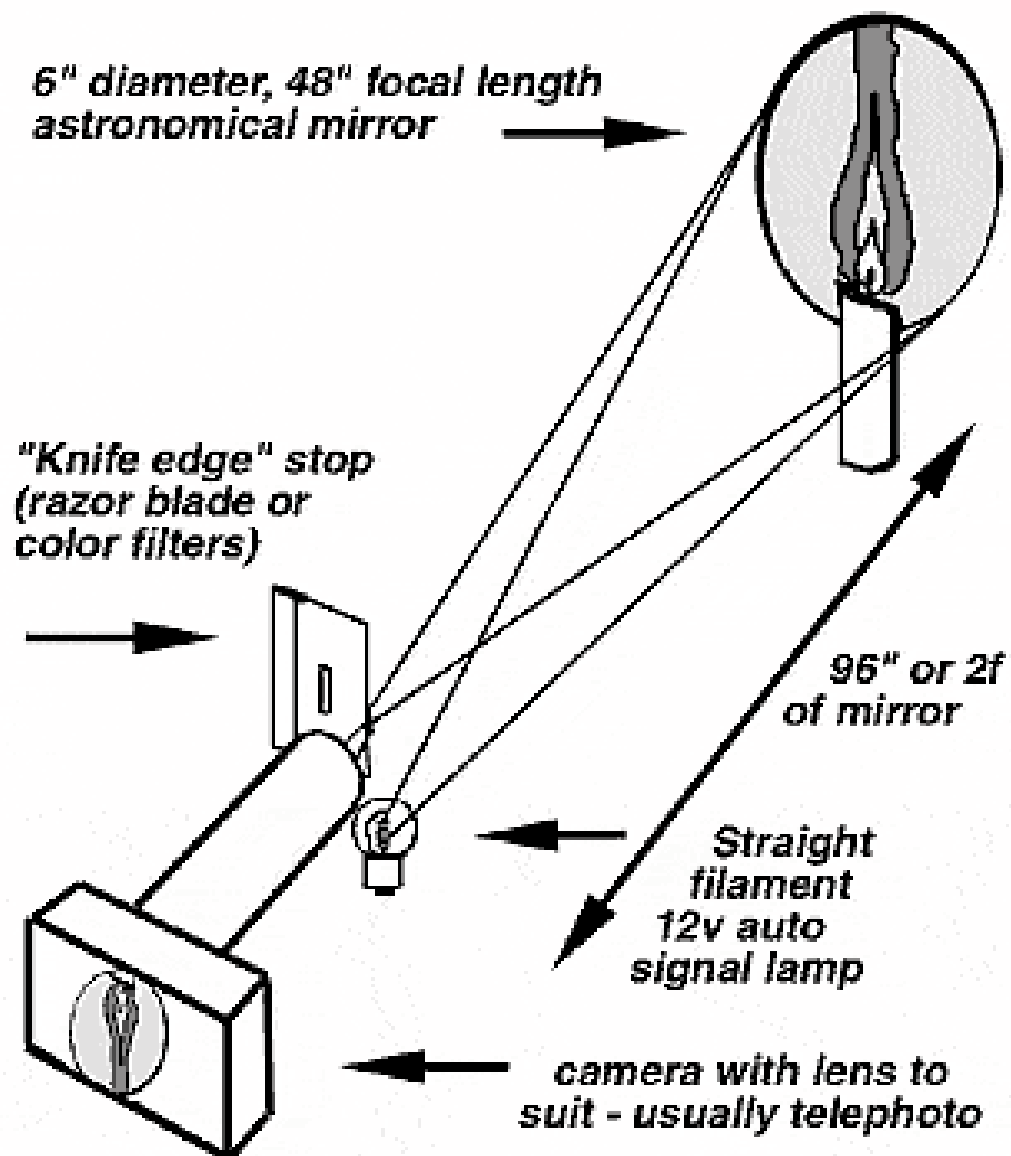


Schlieren



- Alta sensibilidad.
- Relativamente bajo costo.
- Limitación en el campo de visualización dada por los elementos ópticos.
- En la práctica es más bien una visualización cualitativa del fluido.
- Funciona a partir de los gradientes de densidad:

$$\frac{\Delta I}{I_K} = \mp \frac{f}{a_K n_a} \int \frac{\partial n}{\partial y} dz$$

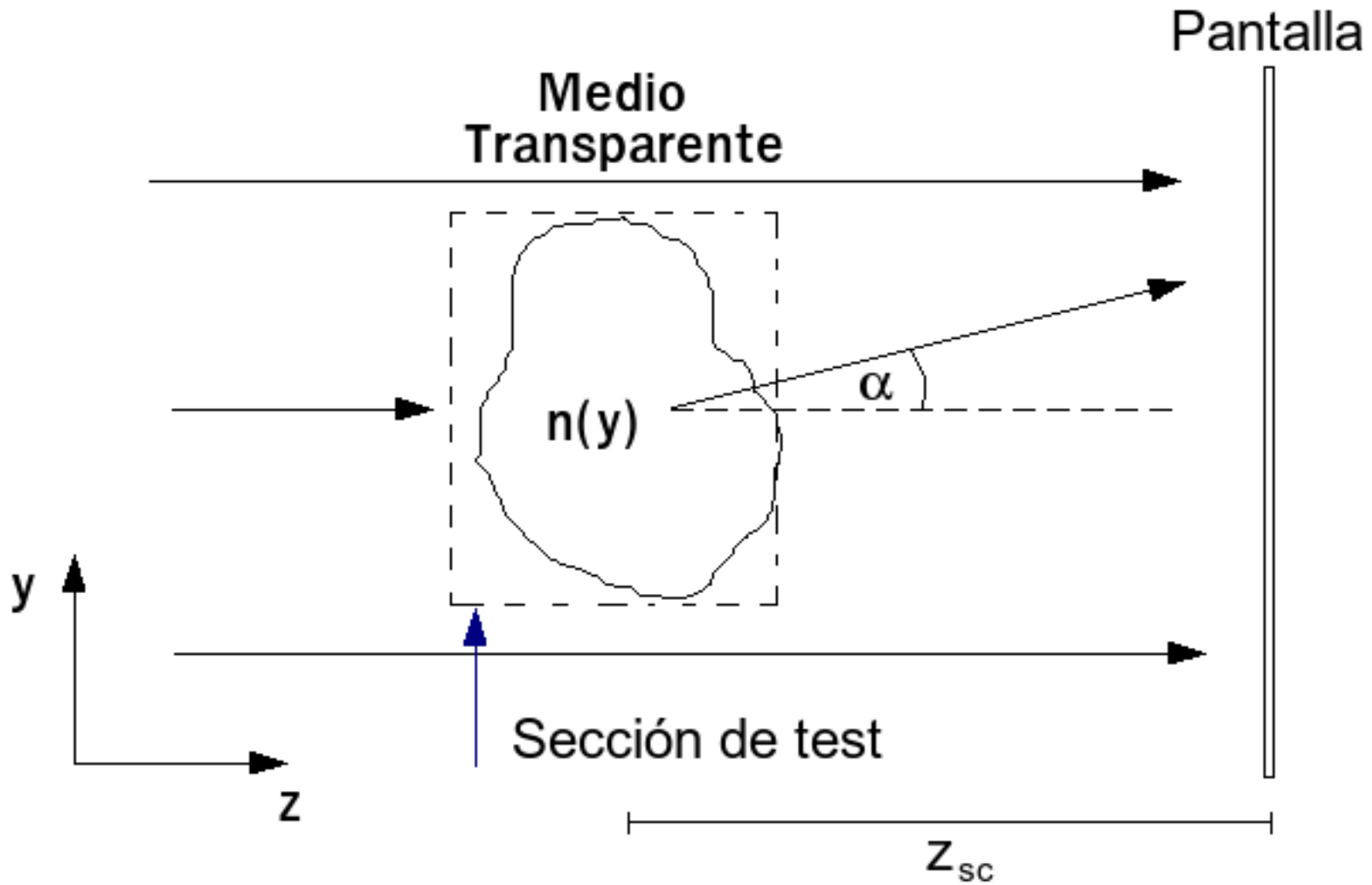


Que observamos a partir de un schlieren???





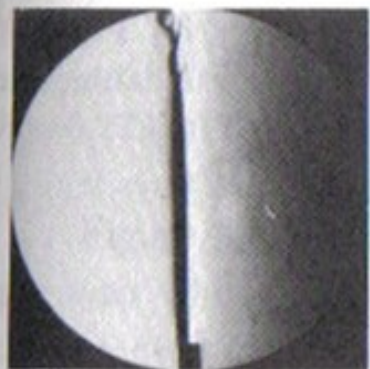
Shadowgrafía



$$\frac{\Delta I}{I_T} = -\frac{z_{sc}}{n_a} \int \frac{\partial^2 n}{\partial^2 y} dz$$



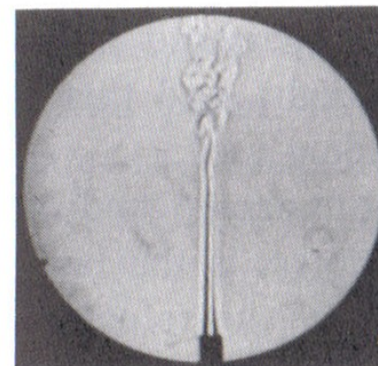
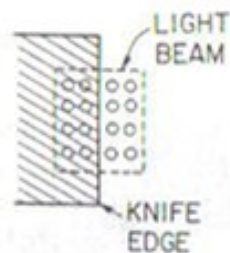
Comparación de las dos técnicas: Jet de helio entrando en atmósfera de aire



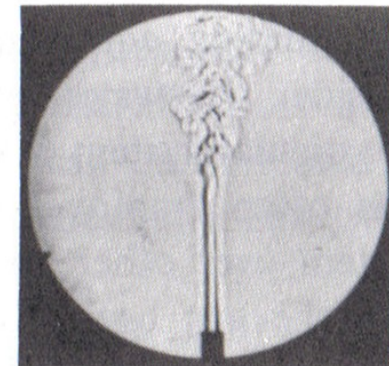
Re 80



Re 200



Re 80



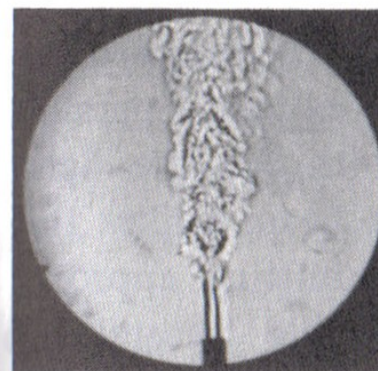
Re 200



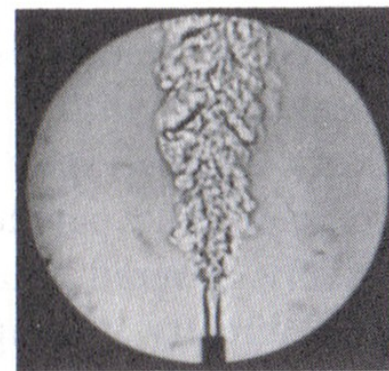
Re 470



Re 630



Re 470



Re 630

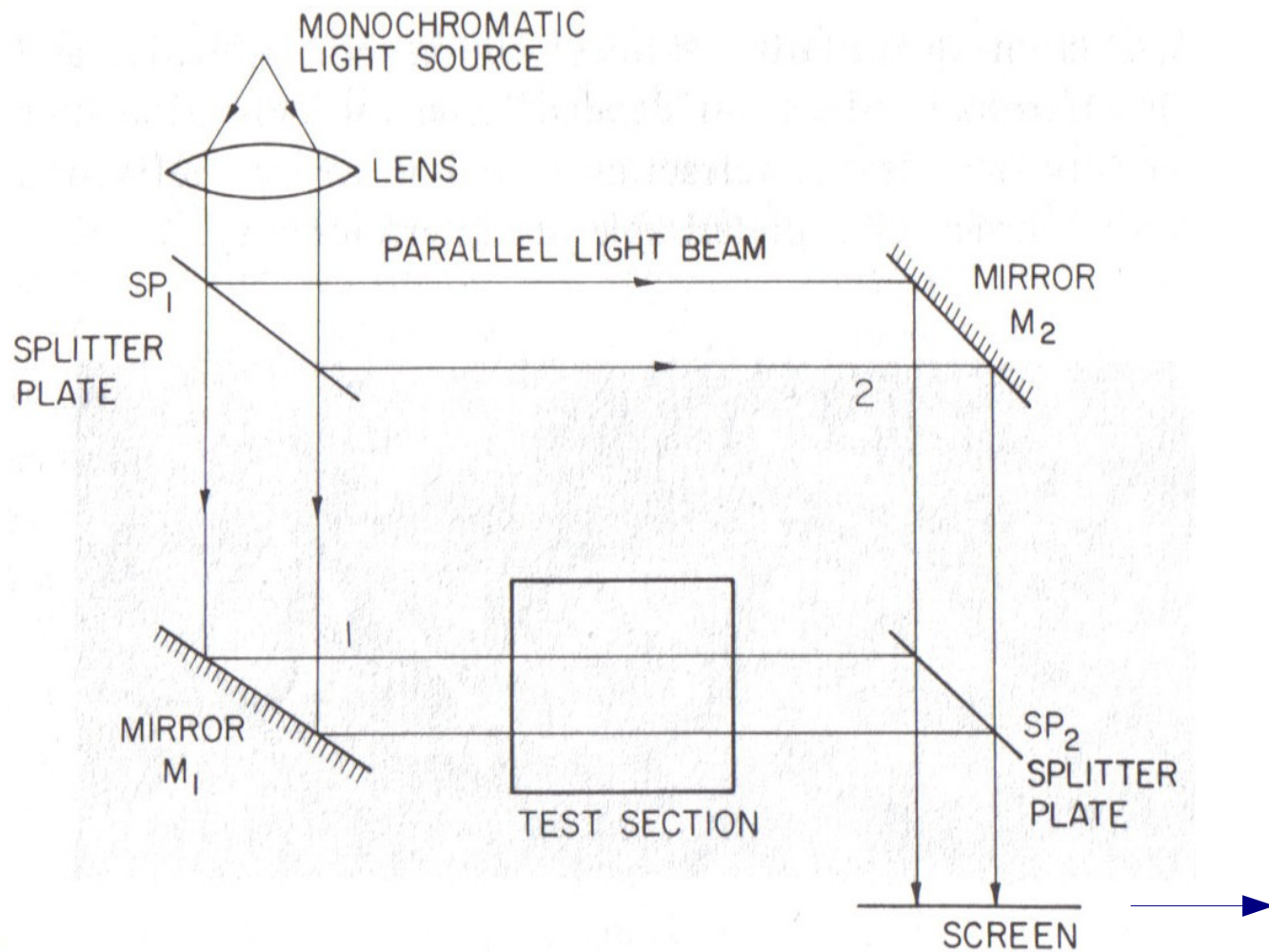
Schlieren

$$Re = \frac{V L}{\nu}$$

Shadow



Interferometría

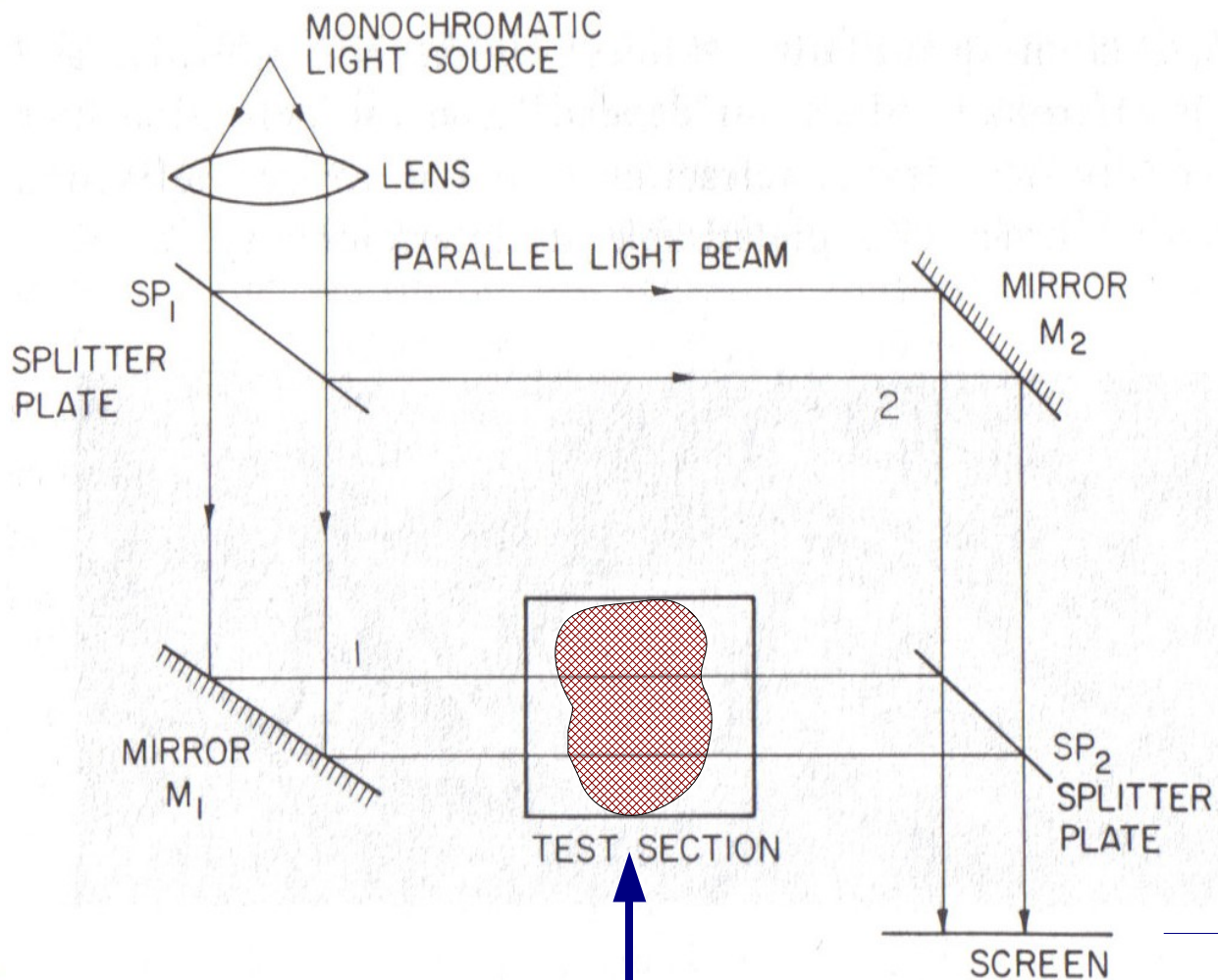


Interferometro de Mach-Zender

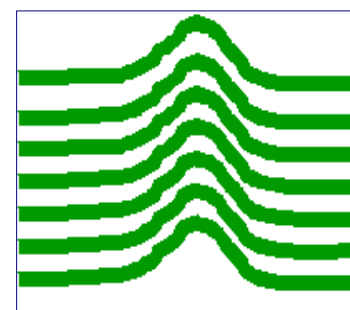




Interferometría



$$\frac{\overline{\Delta PL}}{\lambda_0} = \frac{1}{\lambda_0} \int (n - n_{ref}) dz$$



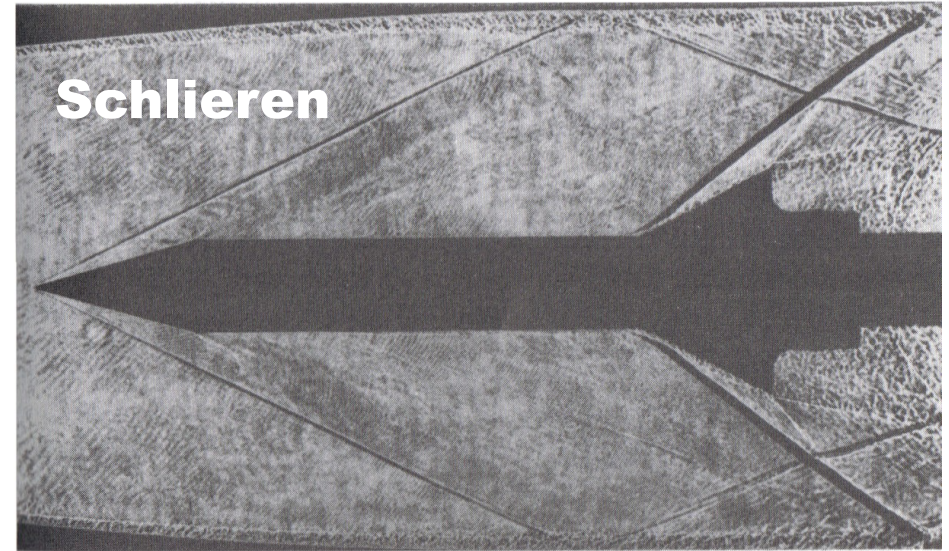
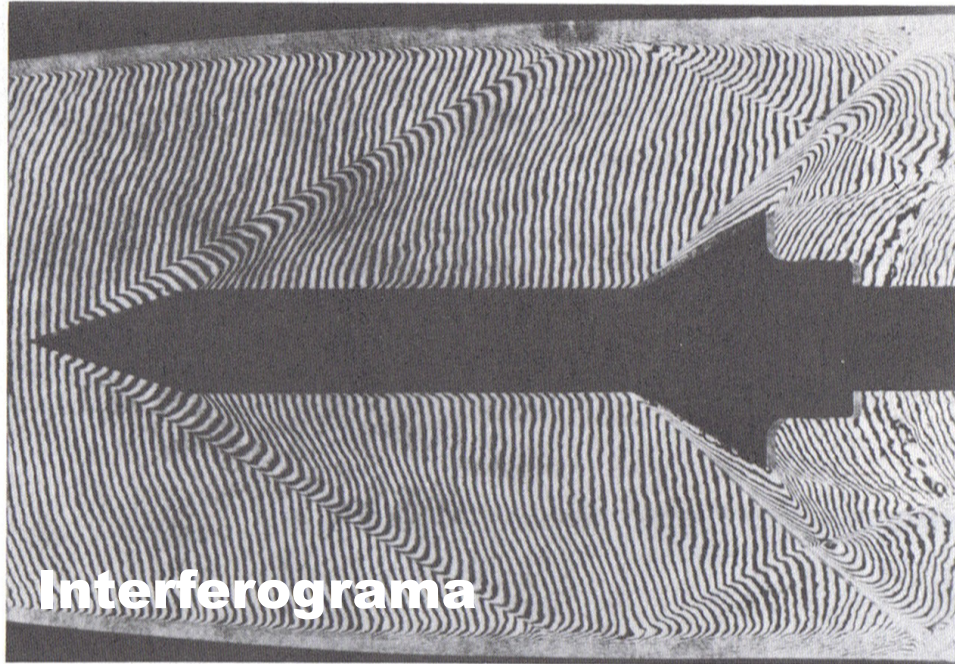
Medio
Transparente



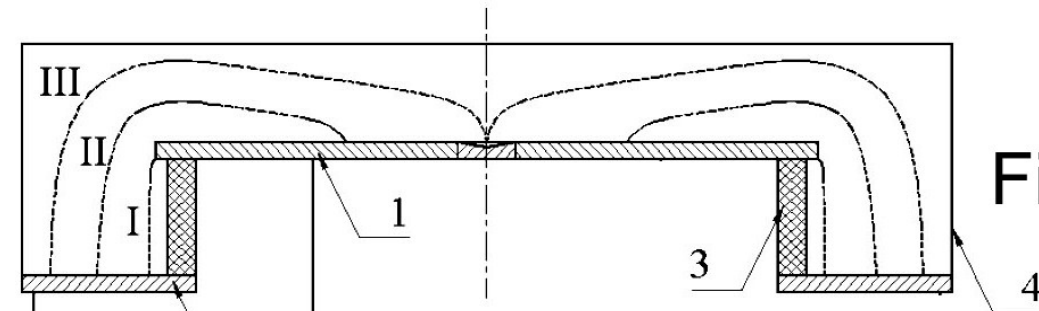
Ejemplos



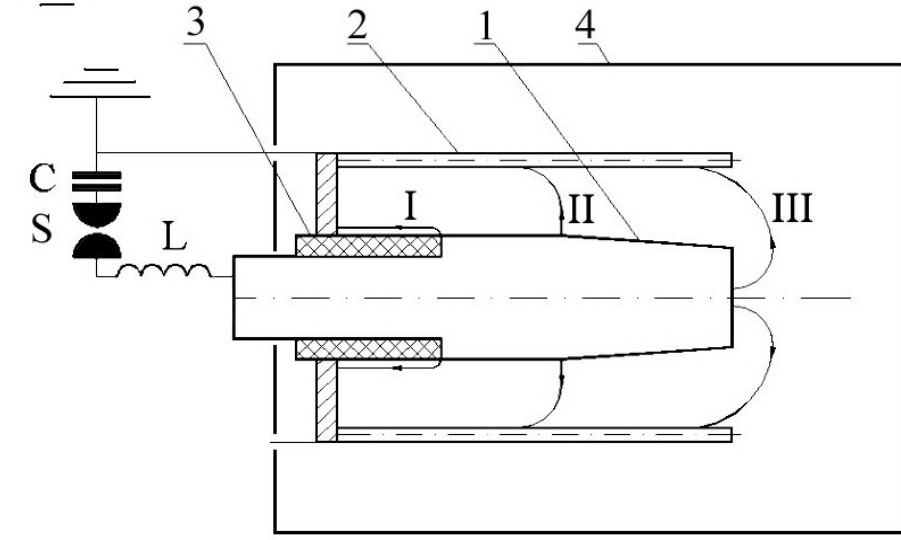
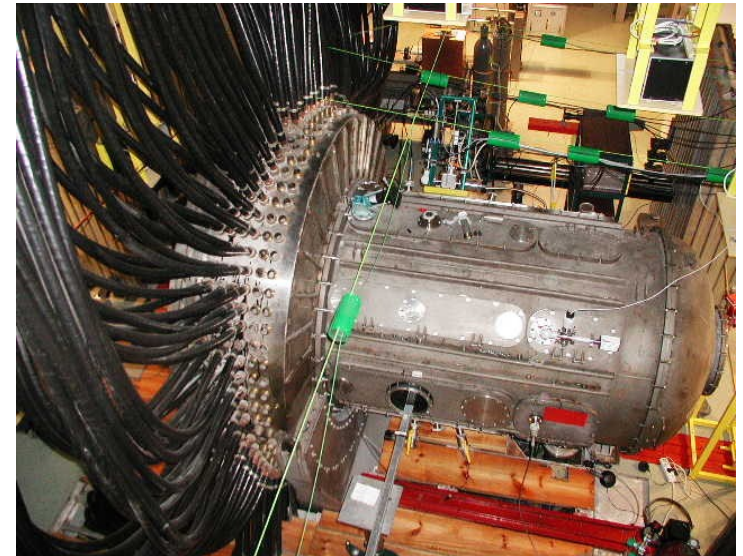
Presion: 100 psia
Ma: 2.98



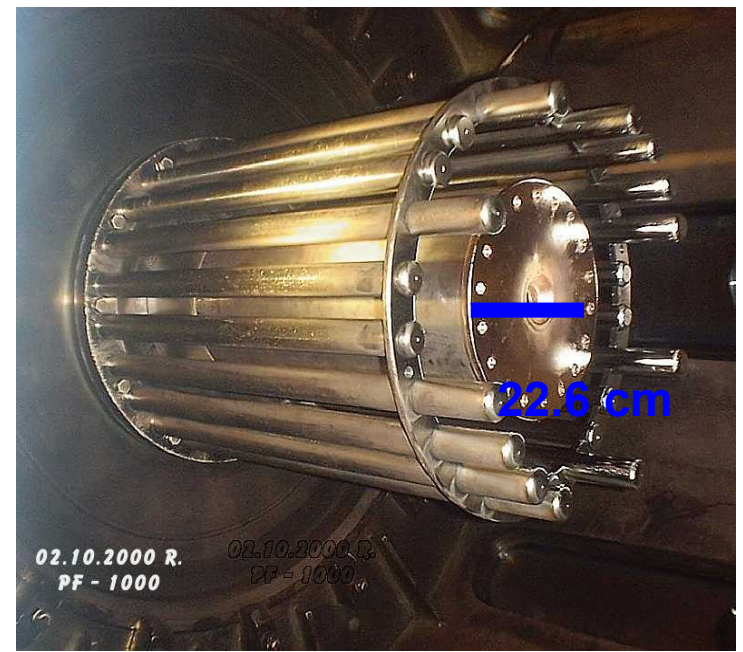
Aplicaciones: Diagnósticos en Plasmas Densos



Filippov



Mather

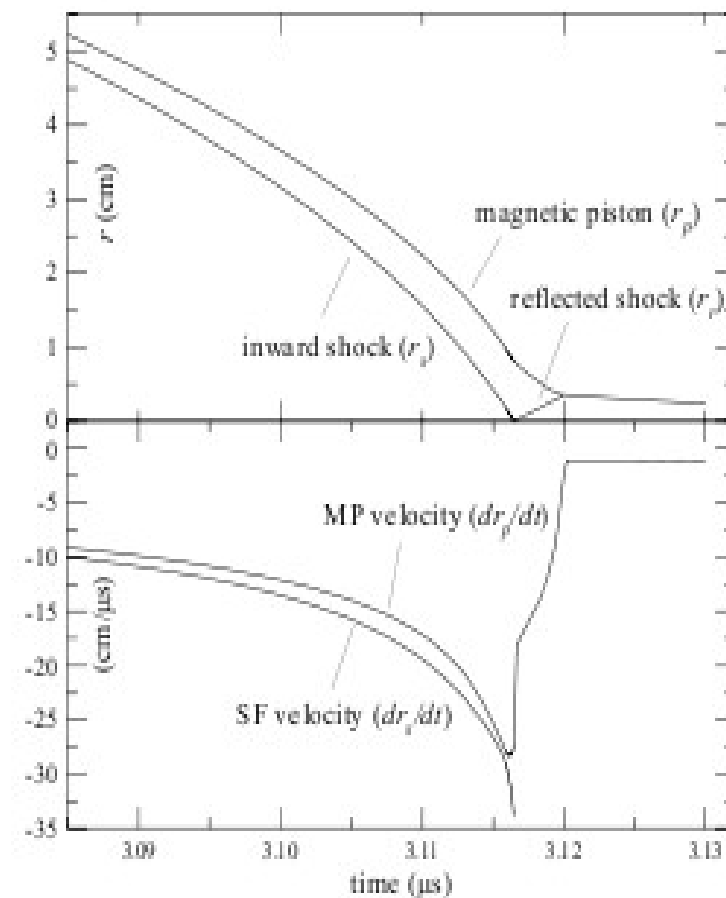
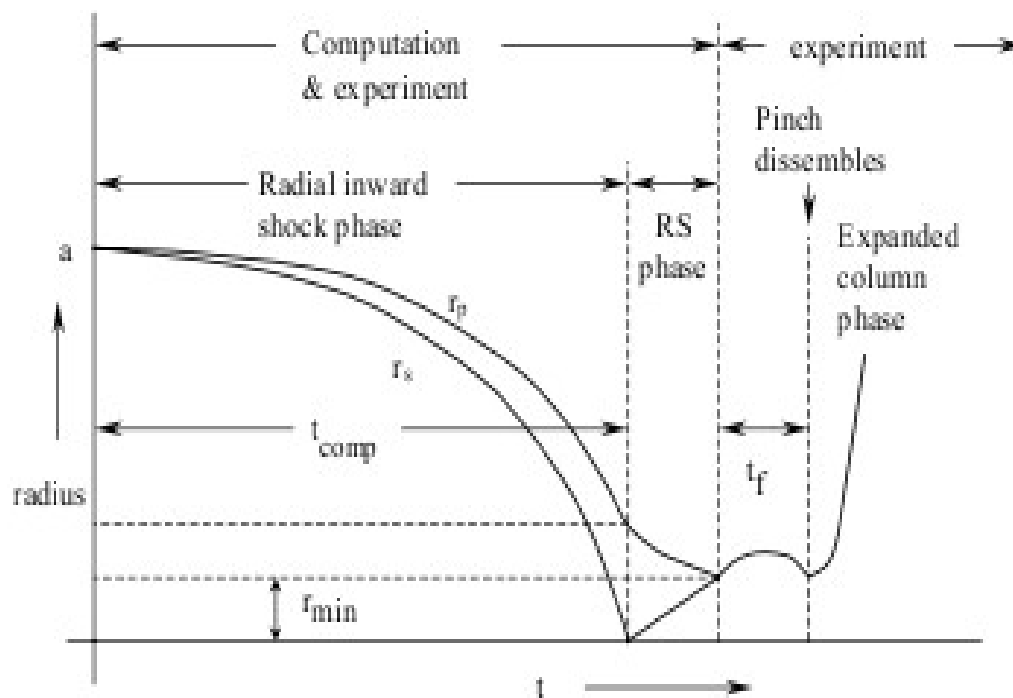
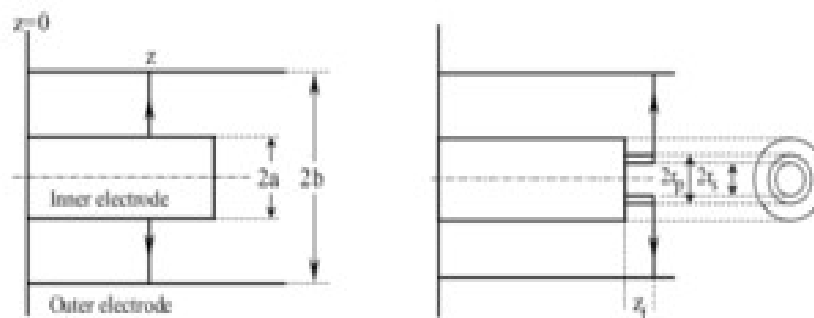




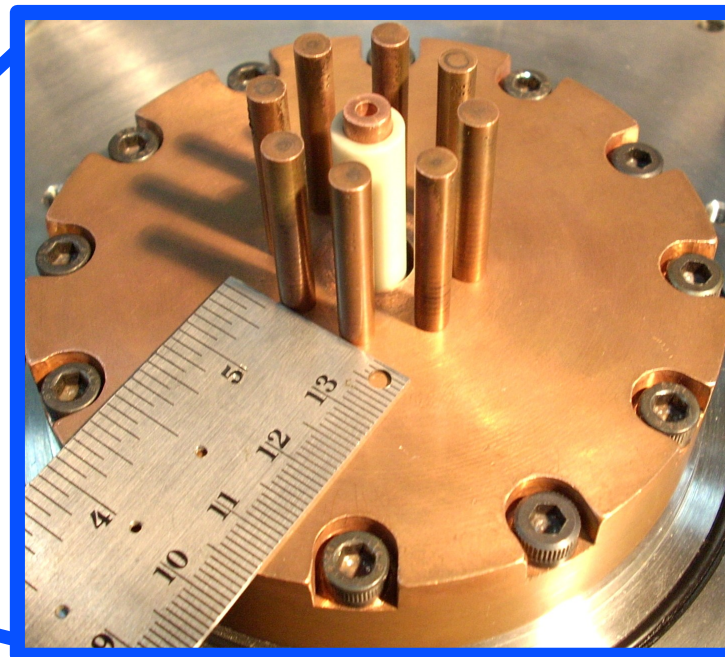
¿Y dónde están las ondas de choque?



Modelo de S Lee:

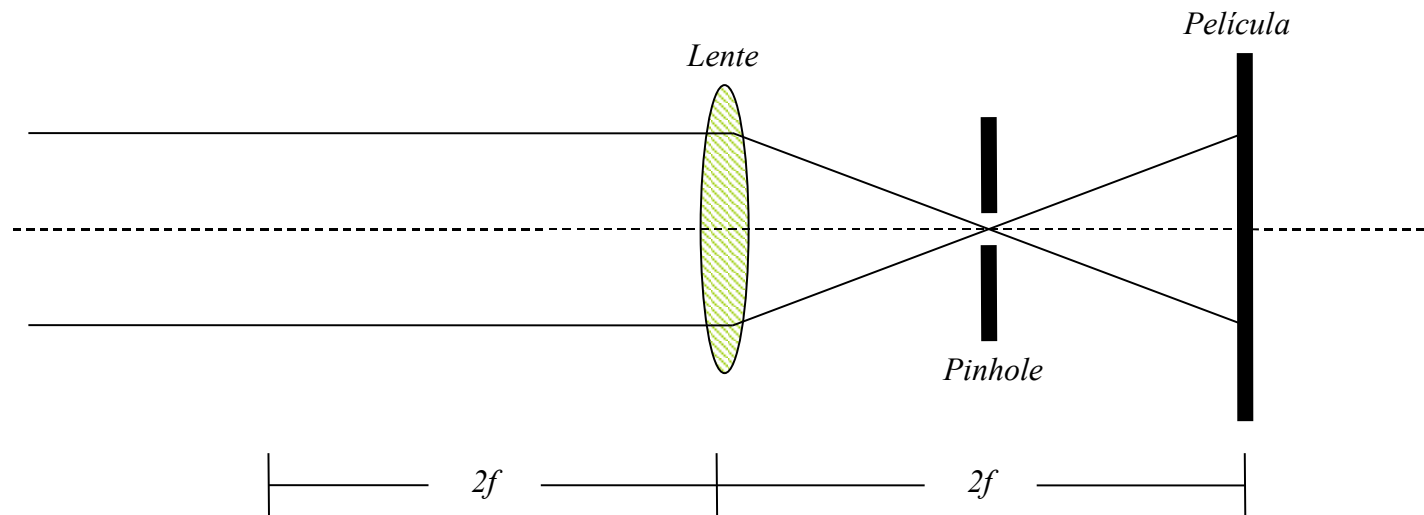


PF-50J: A small Plasma Focus of only Tens of Joules





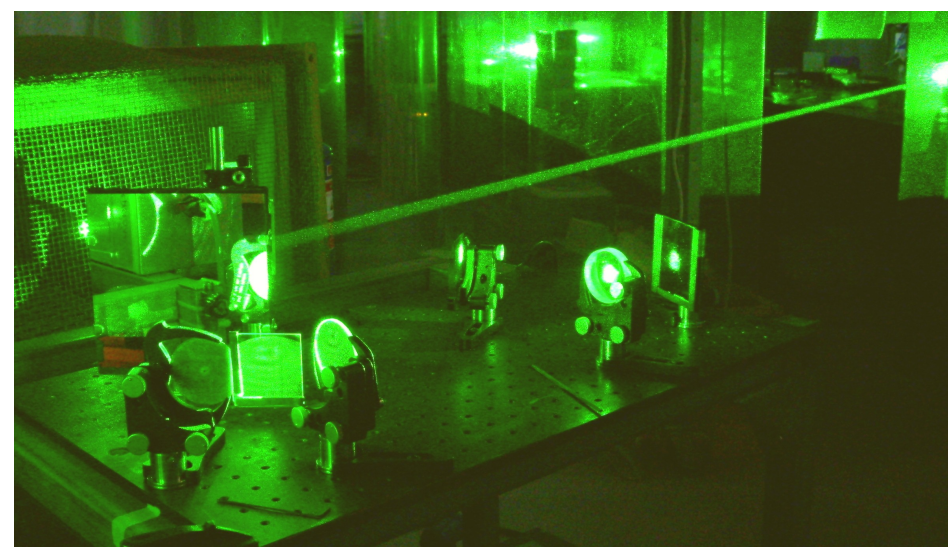
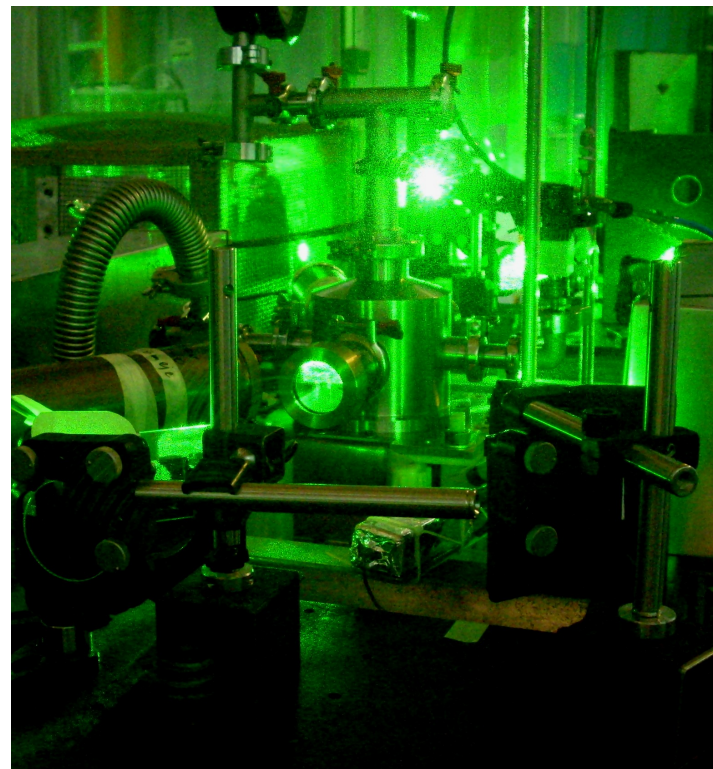
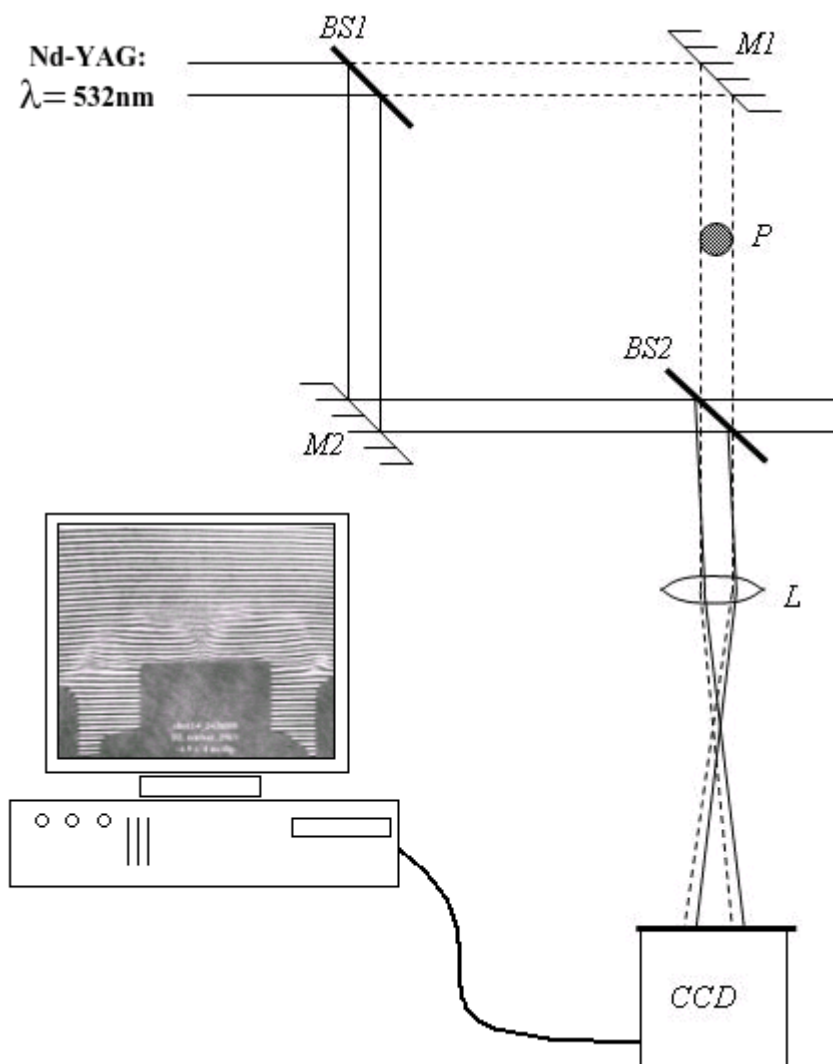
Técnicas experimentales: Schlieren e Interferometría



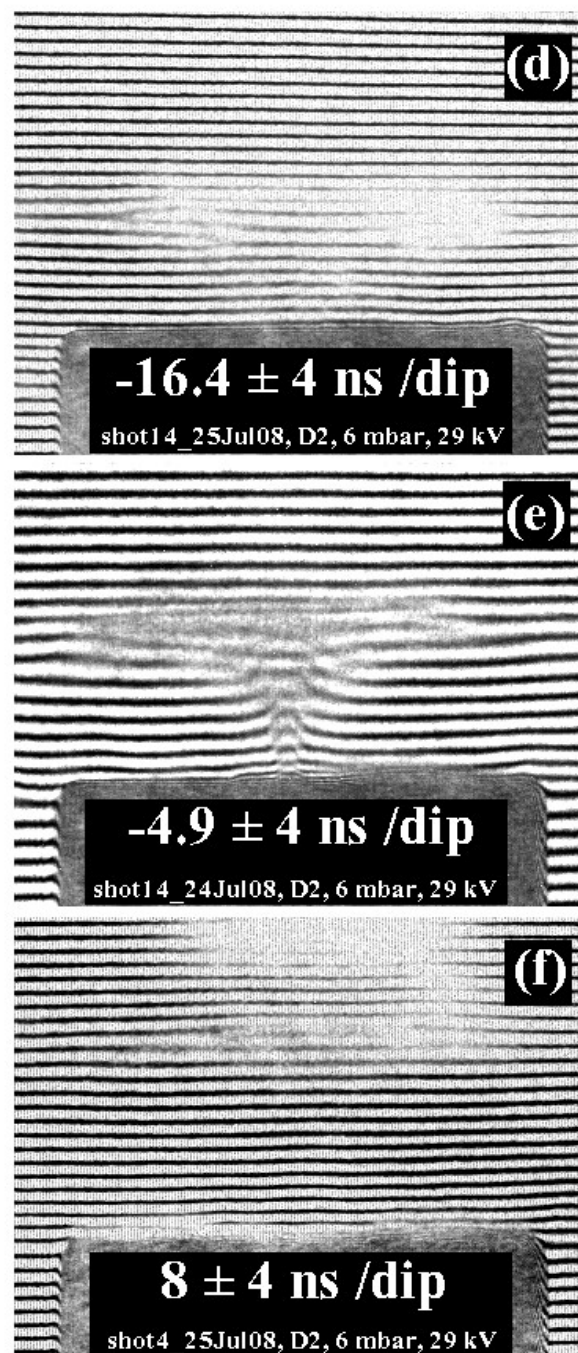
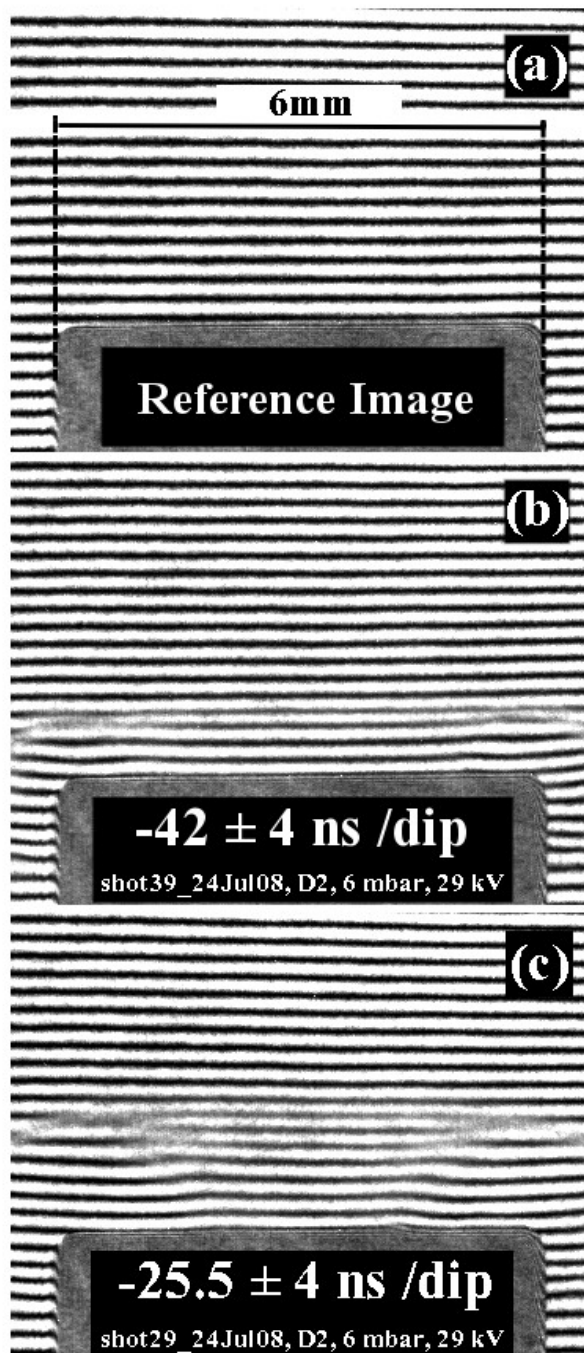
Schlieren: Definir bordes del plasma



Interferometría: Geometría del plasma y densidad en la columna

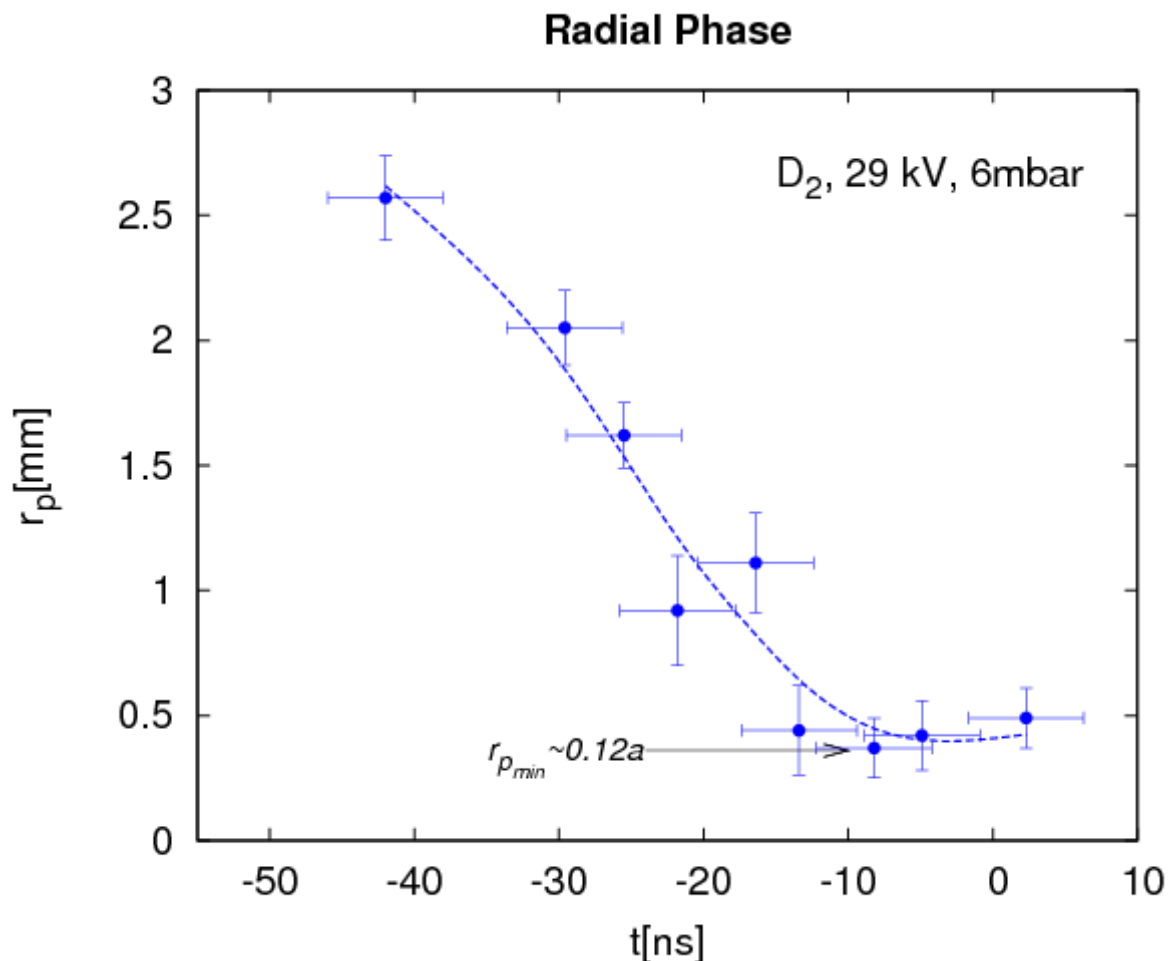


Estudio de la dinámica del plasma





Dinámica en la fase radial para experimentos en D_2



Magnetic piston radial position measurements for Deuterium taken from the last sequence. In this case the maximum piston velocity is estimated to be around 9 cm/us. From interferograms, pinch column radii and column length are also close to the expected values of $\approx 0.1a - 0.2a$ and $\approx a$ respectively.





Mediciones de densidad en la columna

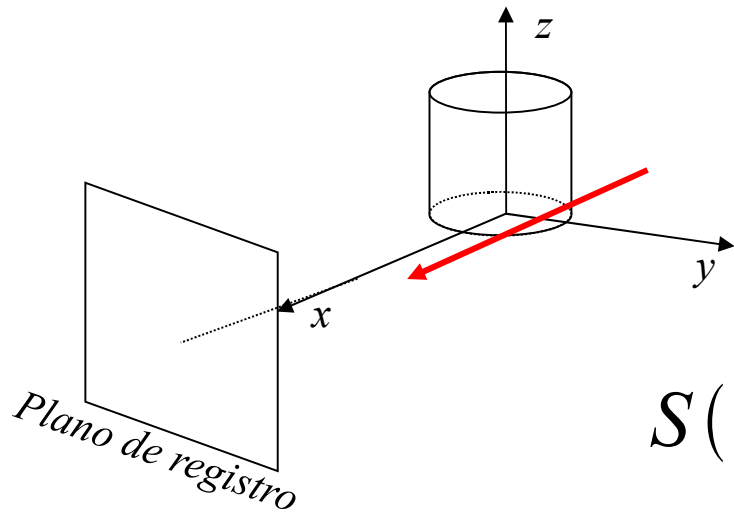


Si $\lambda = 532 \text{ nm}$:

$$\mu_n - 1 = 2.99 \cdot 10^{-30} n_n$$

$$\mu_e - 1 = -1.27 \cdot 10^{-28} n_e$$

En general para un plasma cilíndrico:



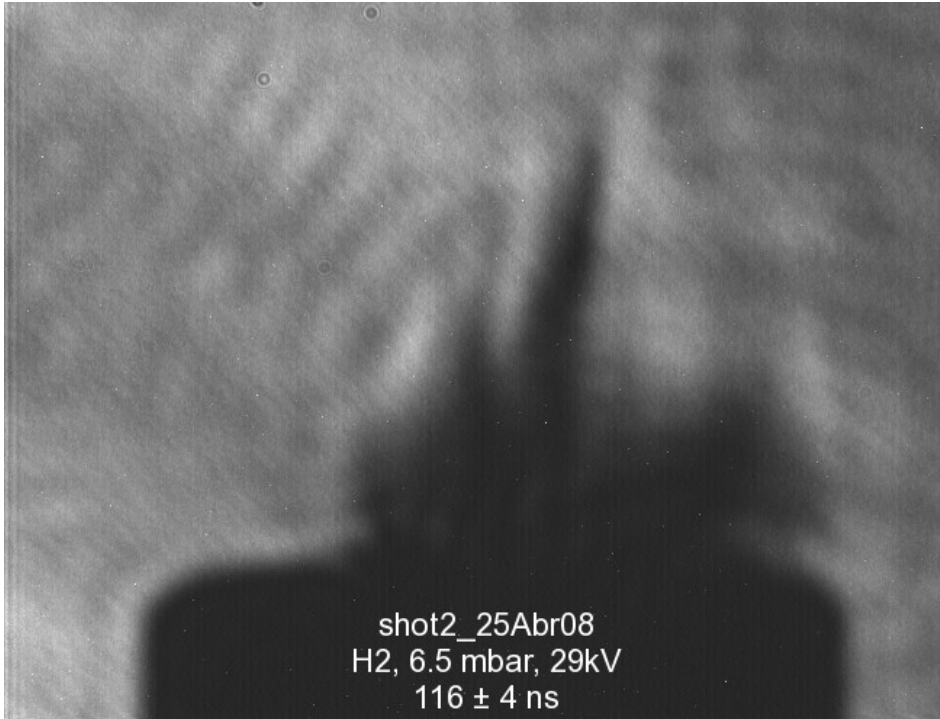
$$S(y) = 4.49 \cdot 10^{-16} \lambda \int_{-(R^2 - y^2)^{1/2}}^{(R^2 - y^2)^{1/2}} n_e(x, y) dx$$

$$N_e = \iint n_e(x, y) dx dy = \frac{4.45 \cdot 10^{15}}{\lambda} \int_0^R S(y) dy$$

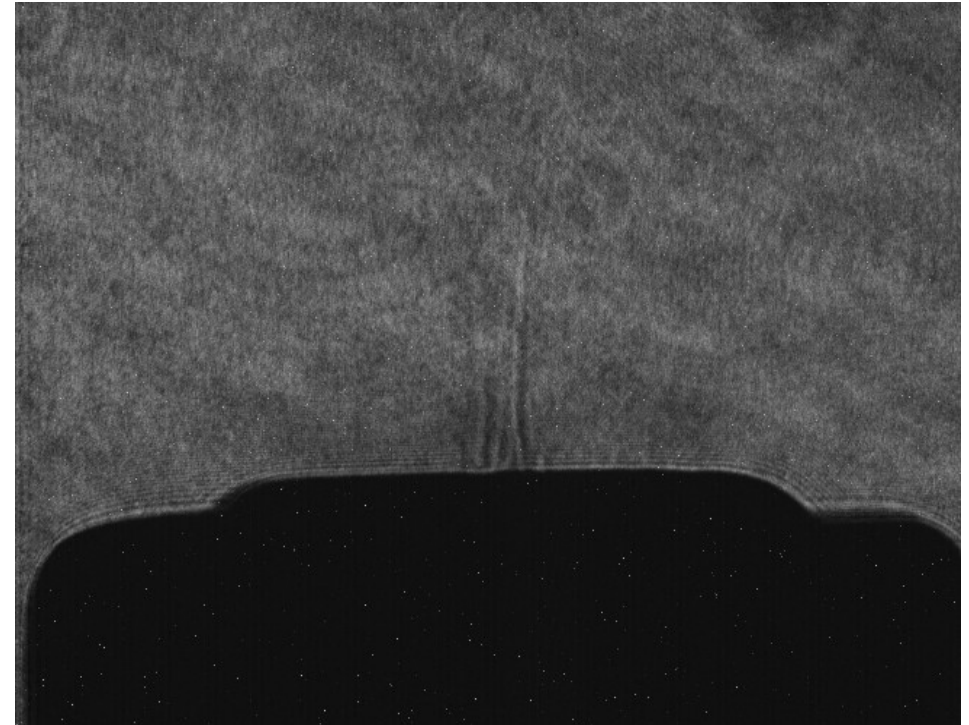




Generación de Jets de plasma a tiempos tardíos de la descarga: Posibles aplicaciones astrofísicas



Schlieren picture. H_2 , 6.5 mbar, 29 kV.
2.5 mm diameter hollow anode, 9 mm deep.



Shadow picture. H_2 , 9 mbar, 29 kV.
200 ns/dip





Shift phase profile

