Coupling collection optics with 1.5 mm optical fiber

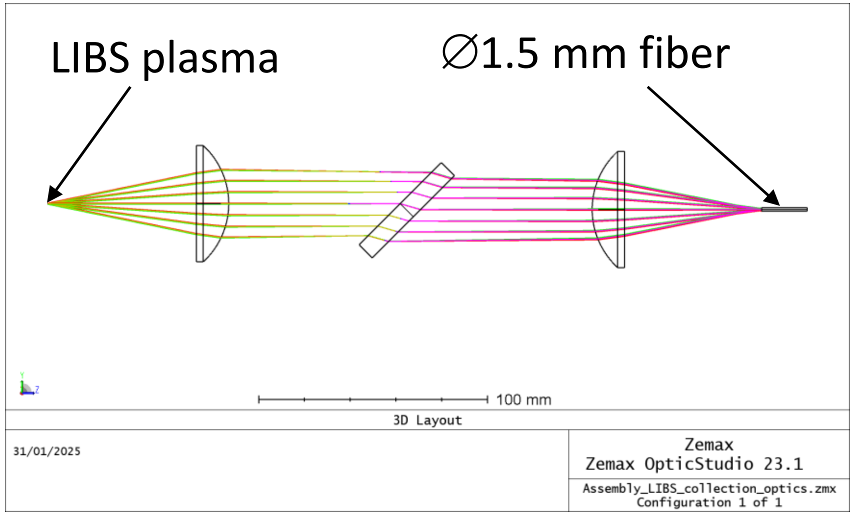


Fig.1 ZEMAX optical model for plasma light-to-fiber coupling calculations

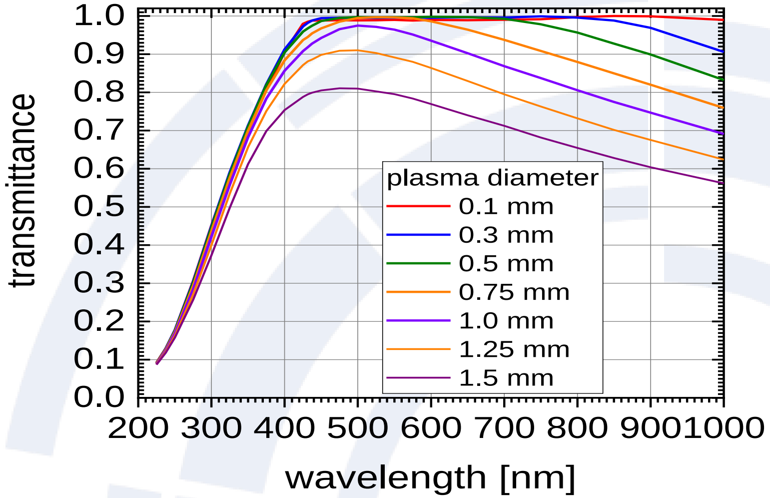


Fig.2 Plasma ligth-to-fiber couplling efficiency versus wavelength for several plasma sizes

- Plasma ligth to fiber coupling depends on both plasma diameter and wavelength
- Due to chromatic abberation transmittance reduces bellow 450 nm
- For plasma diameter ≤0.5 mm, transmittance is independent of plasma diameter within wavelength range of 225 – 700 nm
- For plasma diameter ≤0.5 mm, absolute accuracy of transmittance vs wavelength fitting is better 0.0075
- Calibration with integration sphere do not take into account this effect

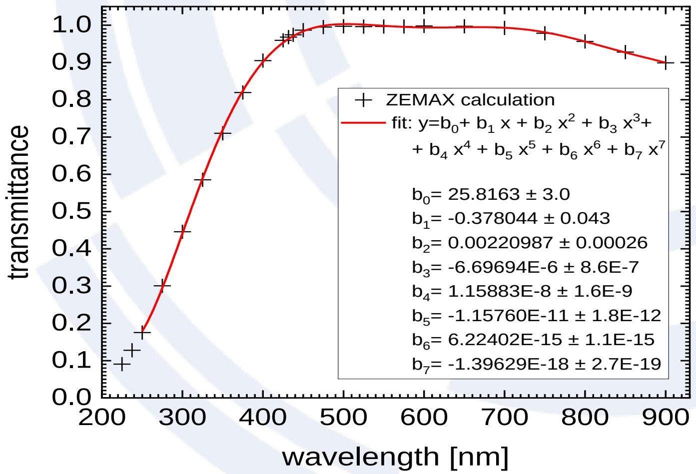
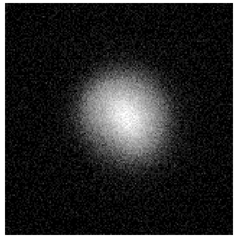


Fig.3 Fitting ZEMAX transmittance data for 0.5 mm plasma

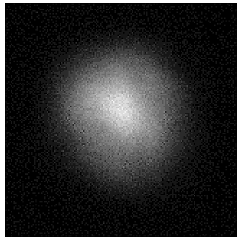
Plasma diameter in JET LIBS like setup

- LIBS optical set-up was build by using optical components identical used on JET-LIBS : lenses and beam splitter
- EKSPLA-PL2241 laser (1064nm , 35ps) with beam diameter 10 mm and enrgy 10 mJ was used
- Gatable MCP+CCD camera with Hα interference filter take photos of plasma image at the fiber end plane

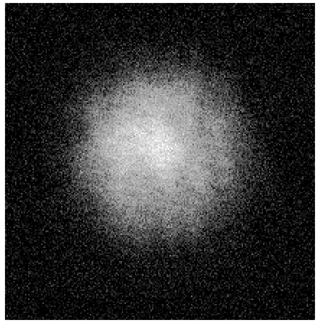
0 ns



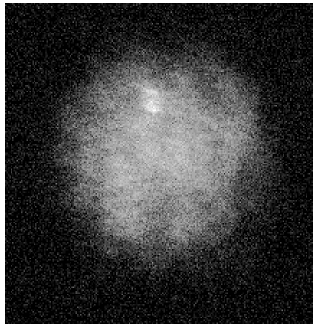
185 ns



580 ns



1430 ns



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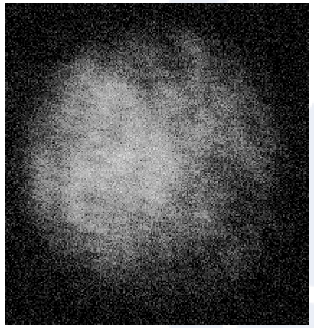
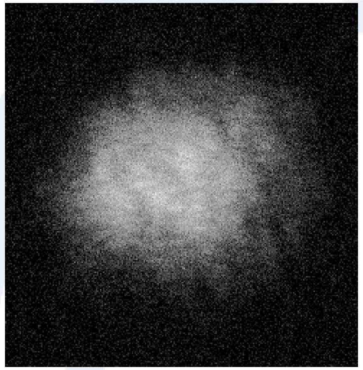
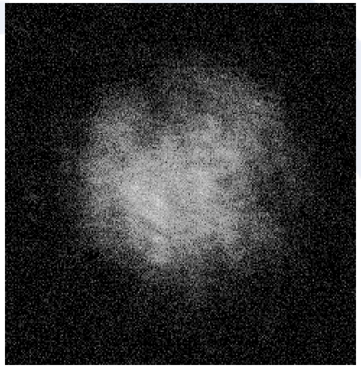


6030 ns



8280 ns



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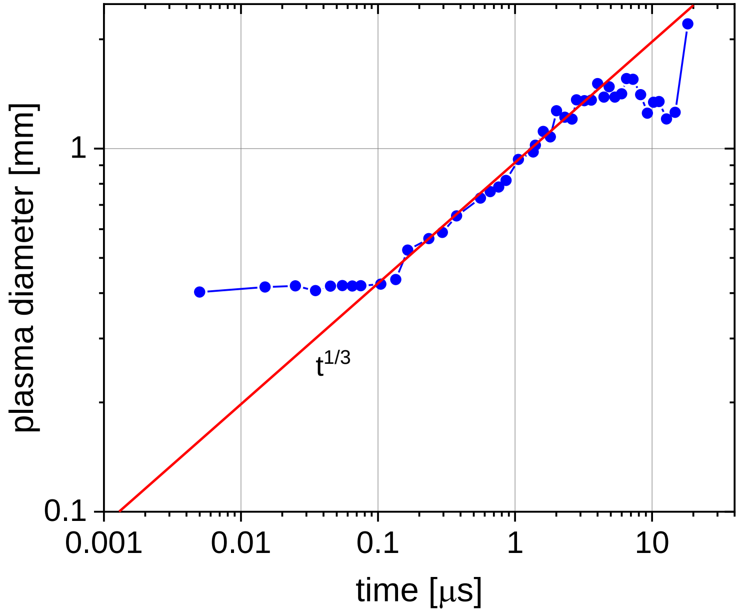
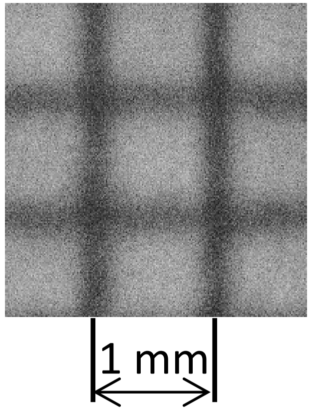
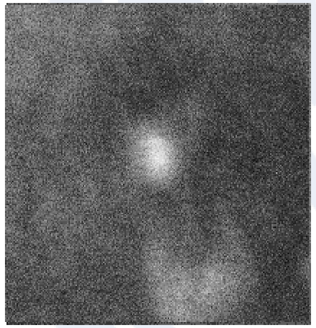


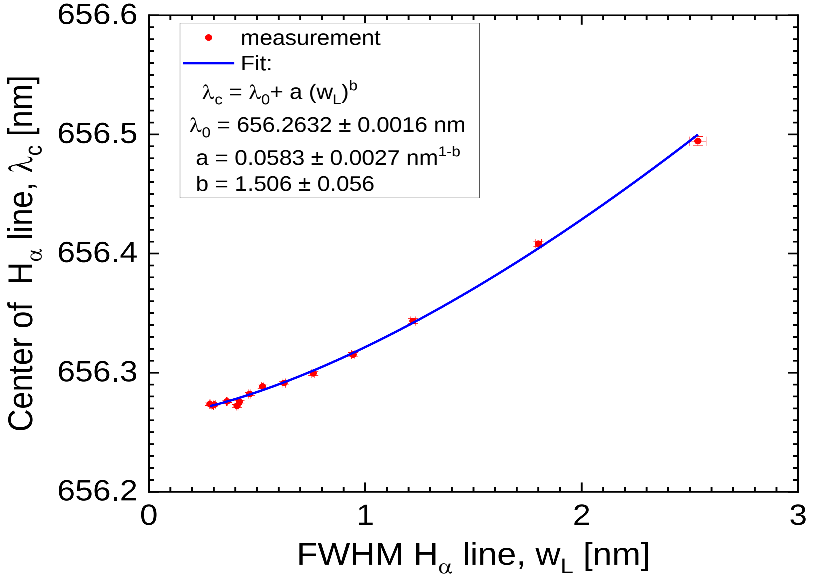




Laser crater on W target

- Image is not sharp due to spherical abberation of the collection optics

Fitting formula for Balmer-α line in laser plasma



Lorentz profile with spectral line shift

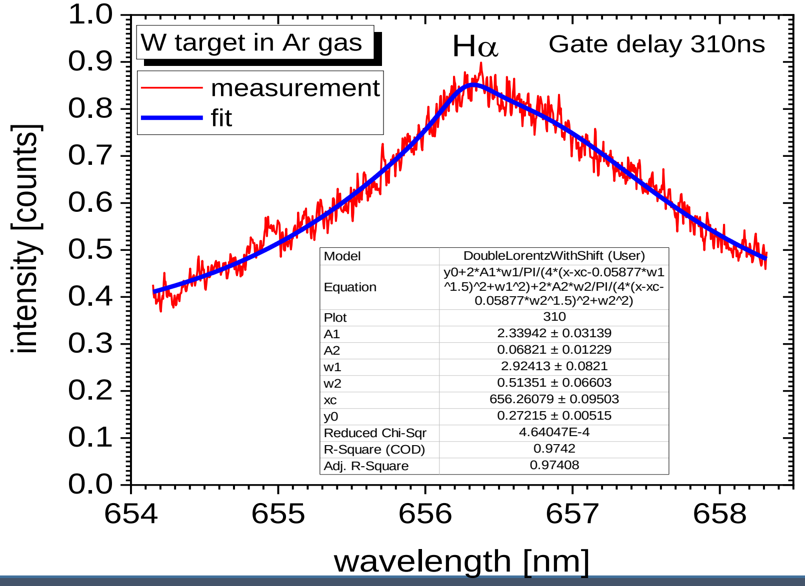
$$f(\lambda) = y_0 + \frac{2\,A}{\pi}\,\frac{w_{FWHM}}{4\,(\lambda-\lambda_w)^2+(w_{FWHM})^2}$$

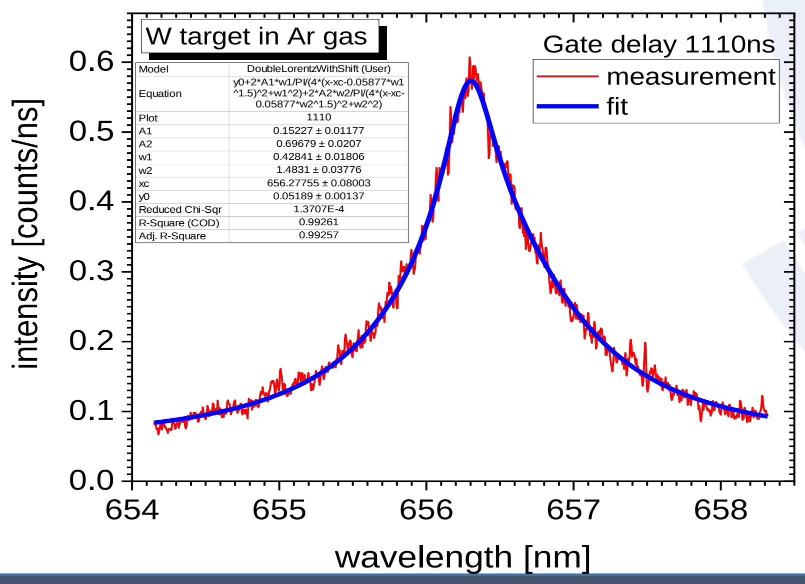
$\lambda_w = \lambda_0 + a\,(w_{FWHM})^{3/2}$ $\quad\lambda_0 = 656.2714\,nm$ $\quad a = 0.05877\,nm^{-\frac{1}{2}}$

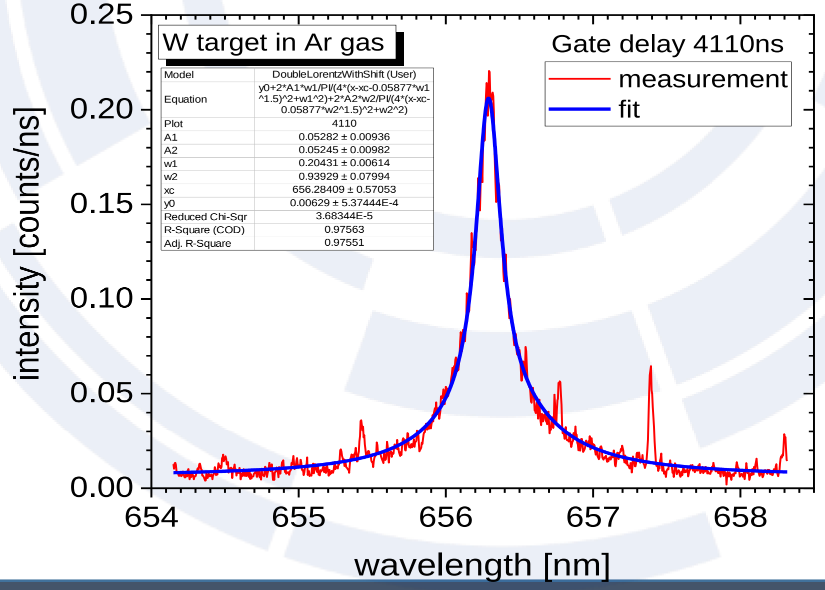
Double Lorentz profile with spectral line shifts

$$f(\lambda) = y_0 + \frac{2}{\pi}\left(\frac{A_1\,w_1}{4\,(\lambda-\lambda_0-a\,(w_1)^{3/2})^2+(w_1)^2} + \frac{A_2\,w_2}{4\,(\lambda-\lambda_0-a\,(w_2)^{3/2})^2+(w_2)^2}\right)$$

Fitting parameters: A_1, A_2, w_1, w_2, y_0 $\quad 0 < A_1$ $\quad 0 < A_2$ $\quad 0 < w_2 < w_1$







Balmer-α line central wavelength

Reference	Hα	Dα	Tα	Hα - Dα	Dα - Tα
mean wavelength	656.27625	656.10081	656.04261	0.17544	0.0582
mean intensity	656.27969	656.09946	656.0406	0.18023	0.05885
Atomic spectral line database from CD-ROM 23 of R. L. Kurucz	656.2797	656.101		0.1787	
NIST (Ritz data)	656.2807	656.1011	656.0416	0.1796	0.0595
Wiki	656.2831				
S.H.Skinner et al., Nuclear Fusion, Vol.35, No 2 (1995) 143-151	656.28	656.104	656.045	0.176	0.059
W.E. Curtis, Proc. R. Soc. London Ser. A 90 (1914) 605.	656.2793				
J. Reader, Applied Spectroscopy, Vol.58, No.12 (2004) 1469-1474	656.27952	656.101		0.17852	
W. L. Wiese and J. R. Fuhr, J. Phys. Chem. Ref. Data, Vol.38, No.3 (2009) 565-719	656.283	656.093	656.039	0.19	0.054
D. L. Hillis et al., RSI,Vol.70,No.1 (1999) 359-362	656.279	656.103	656.044	0.176	0.059