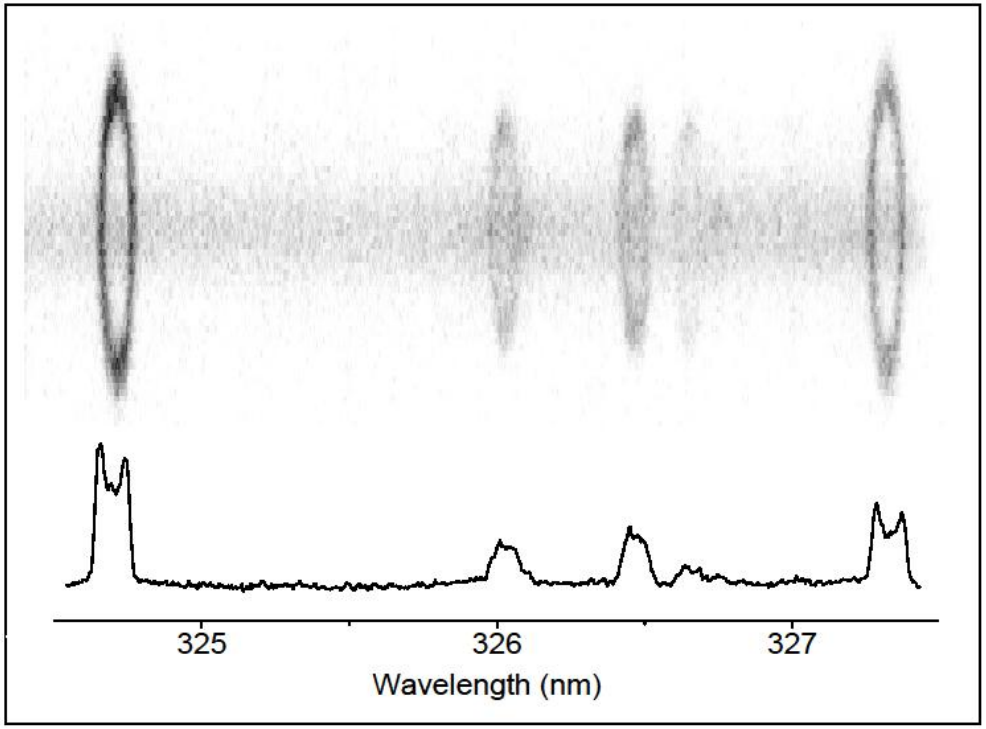
UNCOMMON LINE SHAPES OF Cu I LINES IN LASER INDUCED PLASMA



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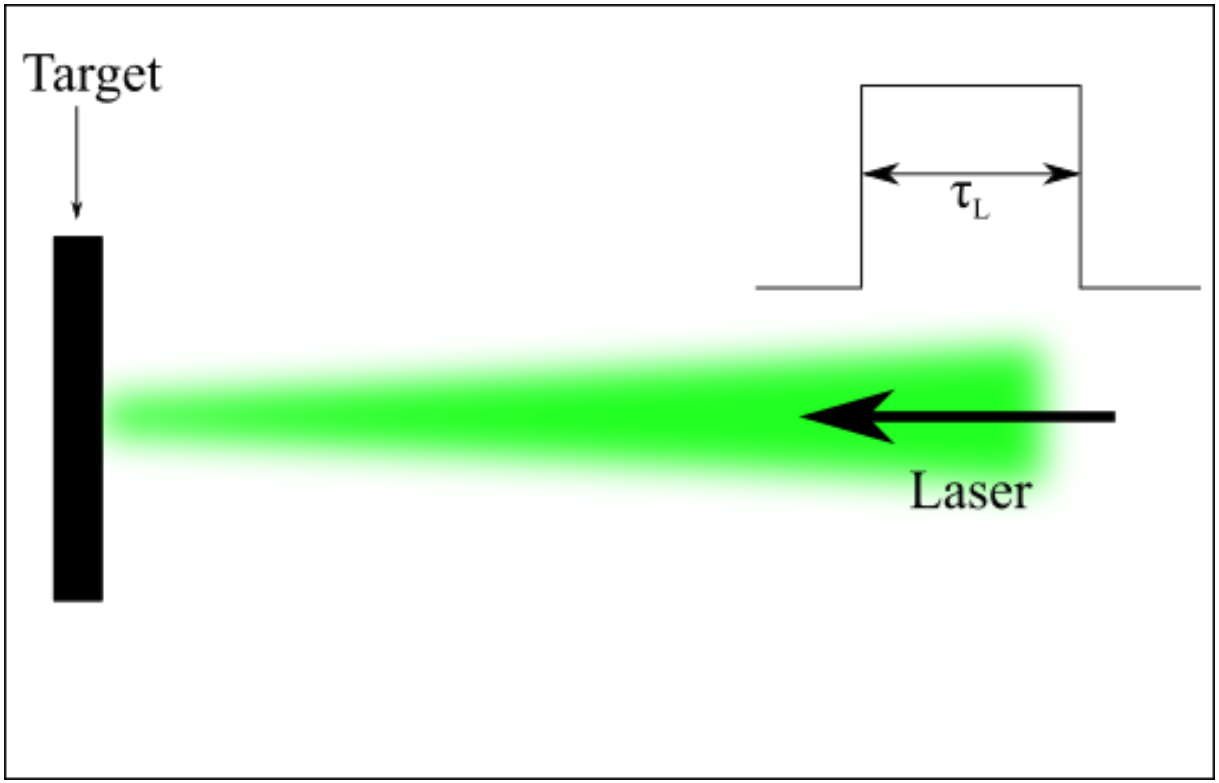
Laser induced plasma – general characteristics

$t < \tau_L$

- **Absorption of laser radiation on the metal target**
- **Heating and melting of the metal target**
- Target evaporation
- Absorption in the plasma plume

$t > \tau_L$

- Fast plasma plume expansion
- Plasma cooling
- Shock wave formation



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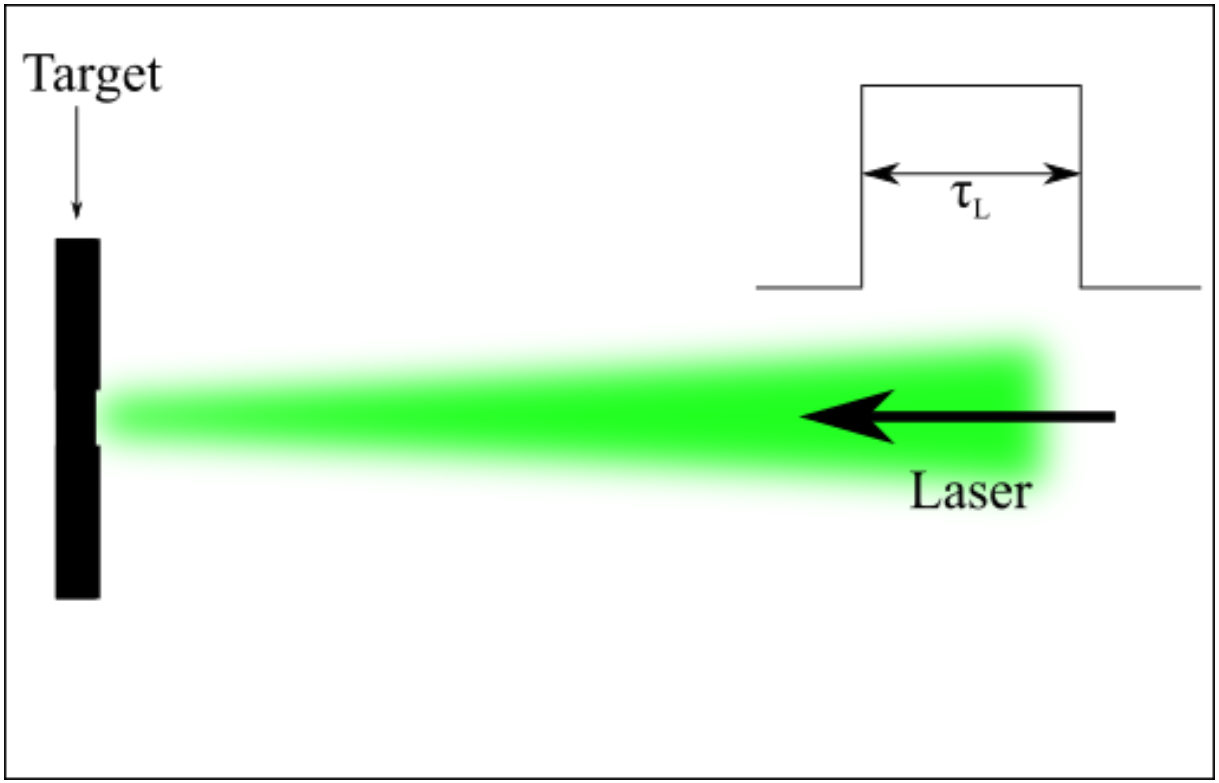

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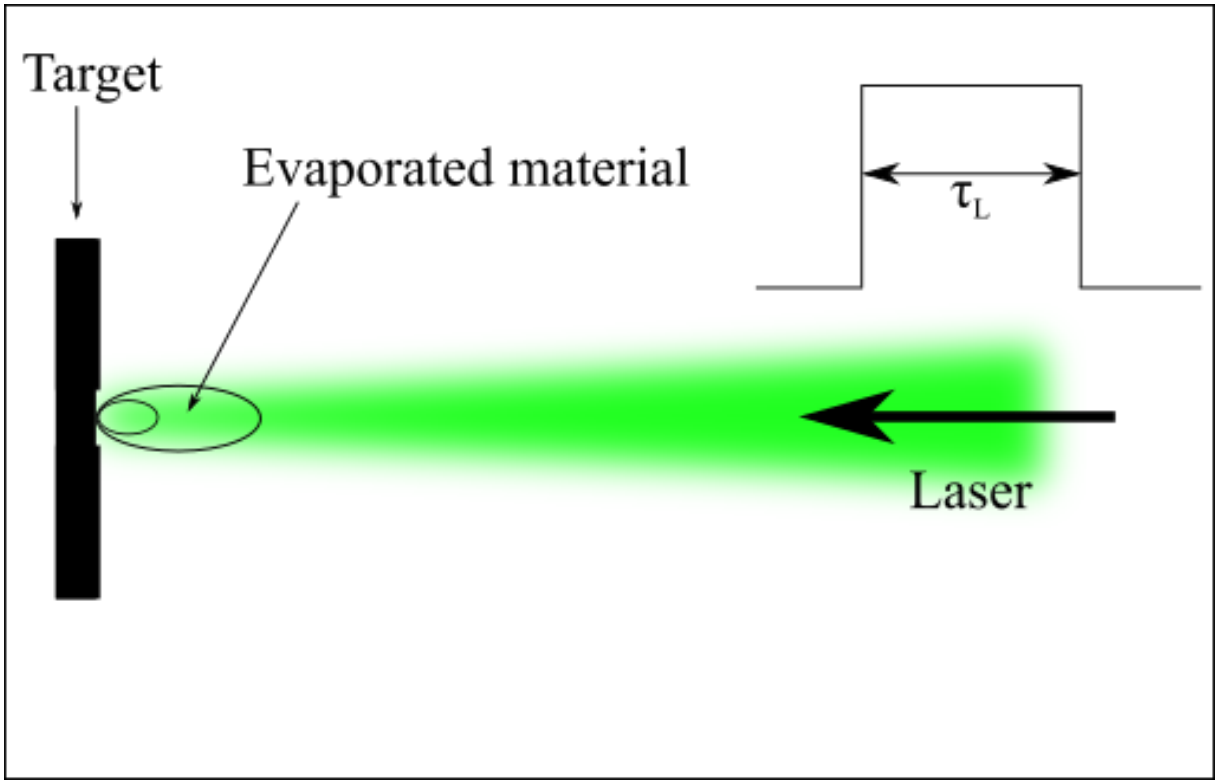

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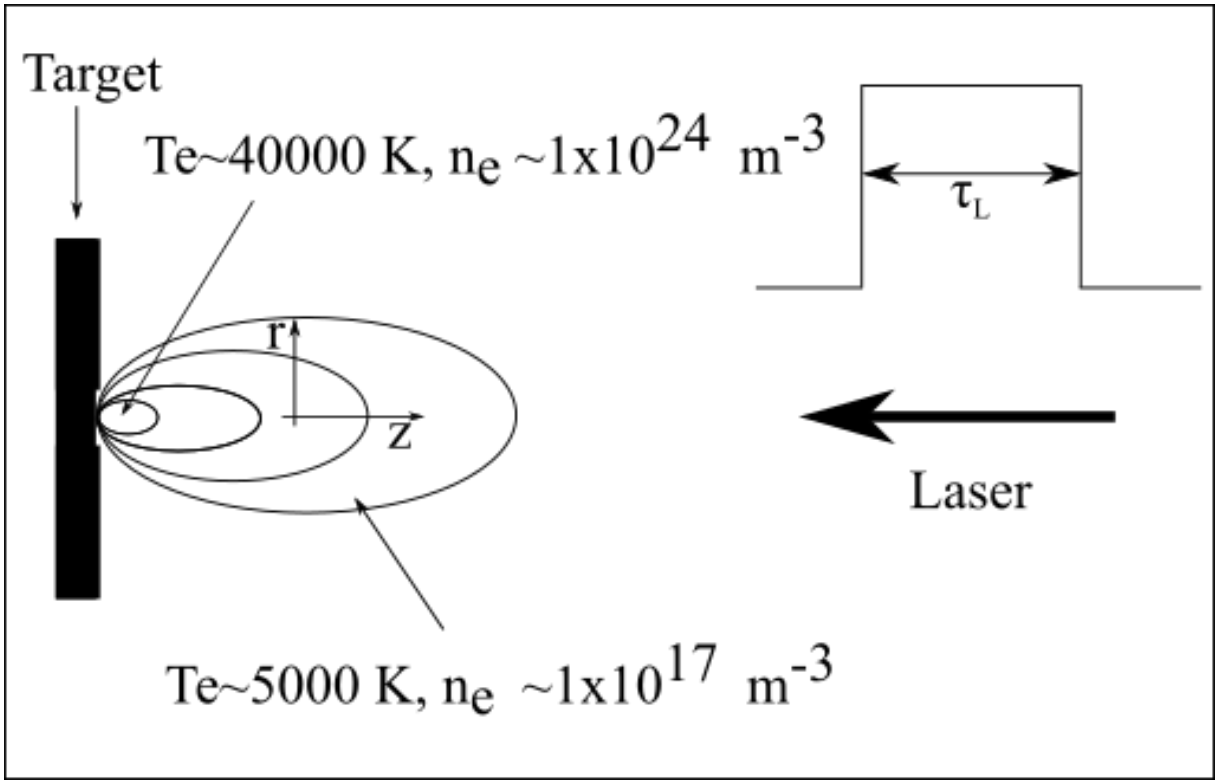
***p* ≈ 20 Pa**
***t* ≈ 1 μs**



***T(r,z)* ≈ 40000 – 5000 K**

***n_e(r,z)* ≈ 10^{24} – 10^{17} m^{-3}**

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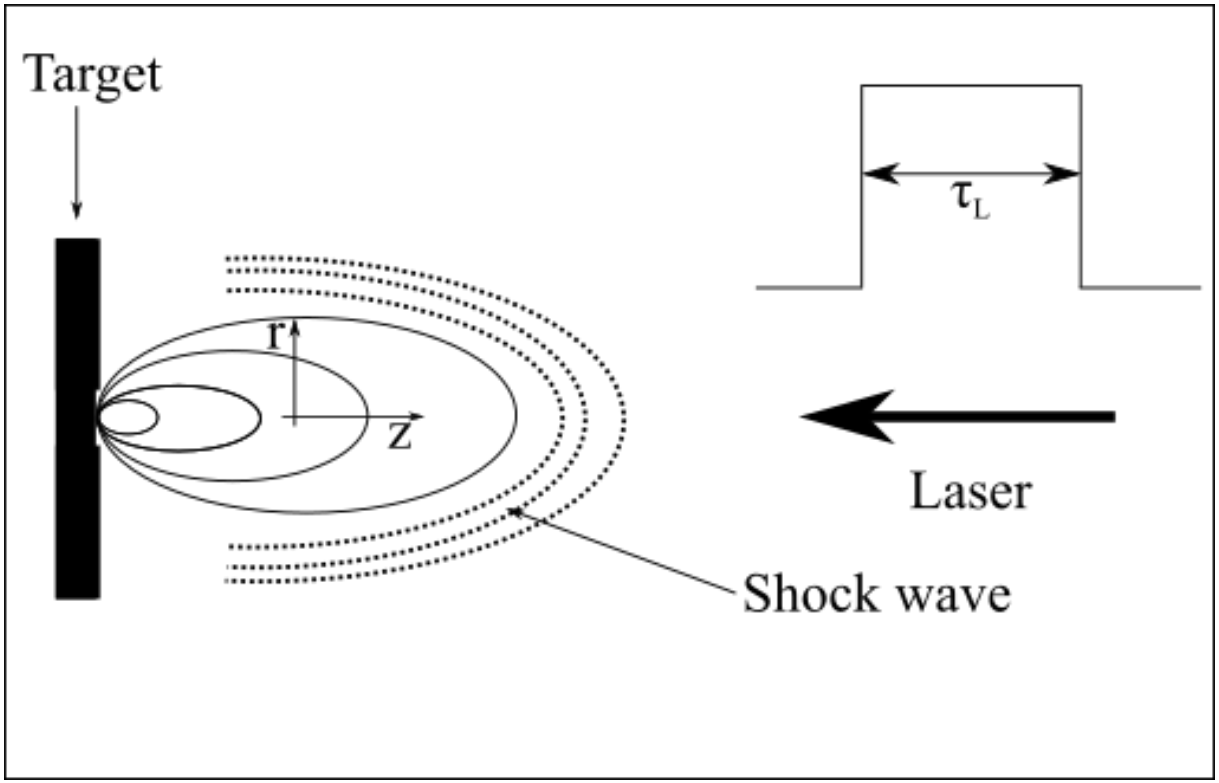
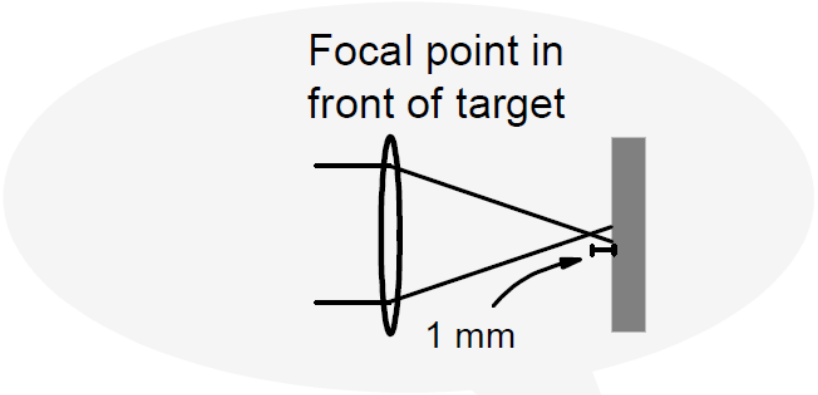
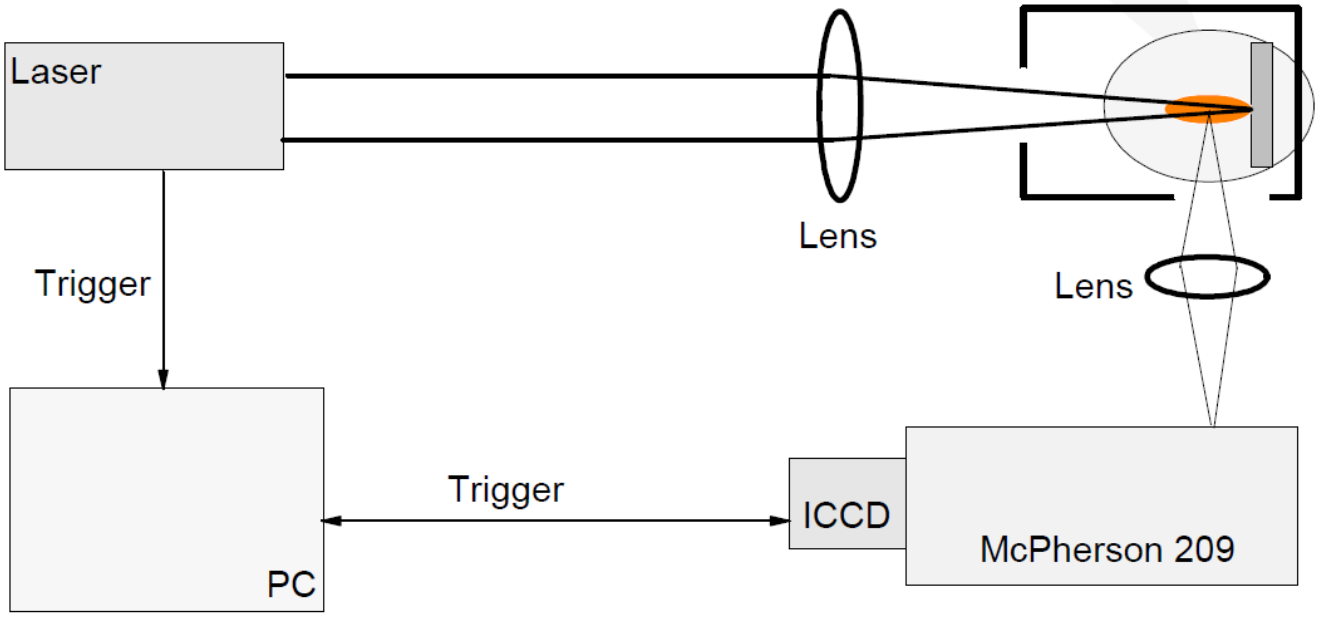


***T(r,z)* ≈ 40000 – 5000 K**

$n_e(r,z) \approx 10^{24} - 10^{17}\ m^{-3}$

Setup

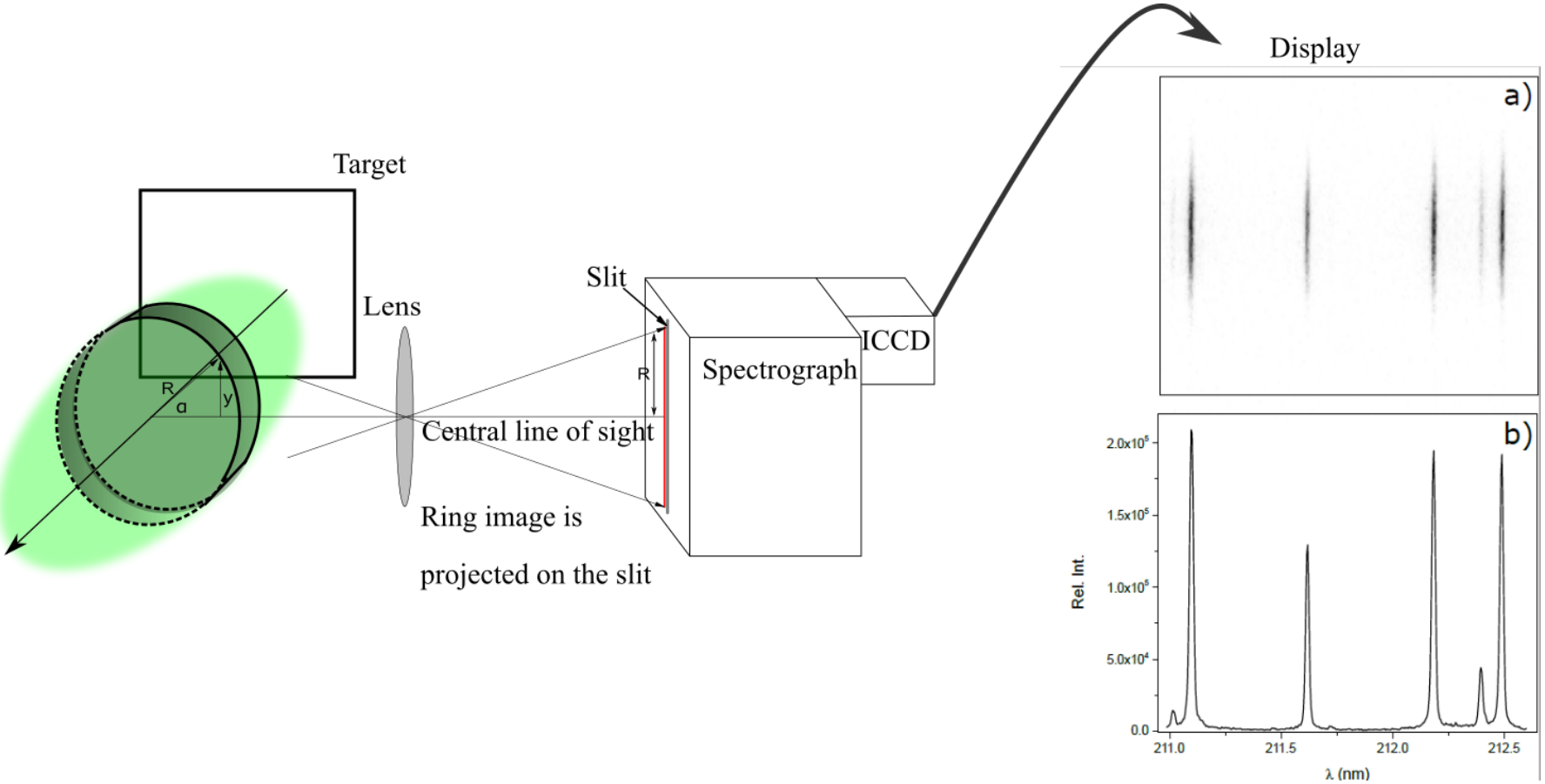


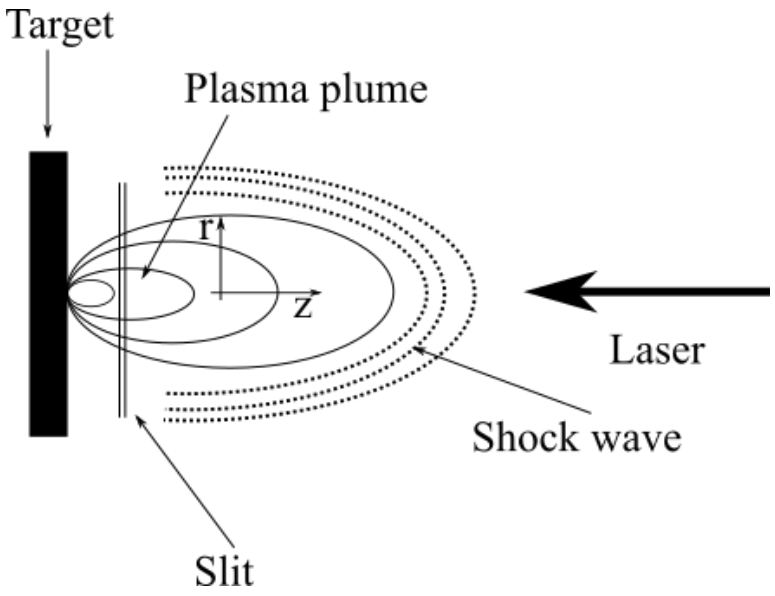


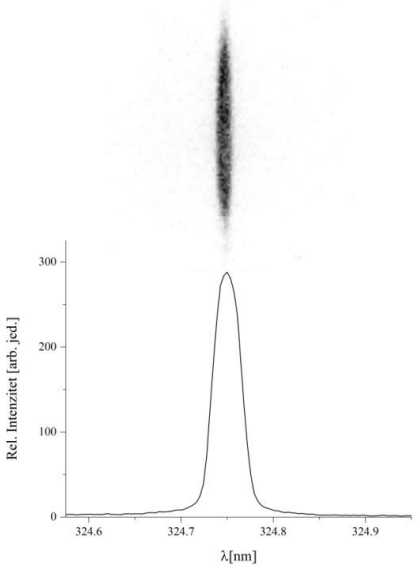
Laser: Nd:YAG
Energy output: 1 J
Pulse width: 5 ns
$\lambda = 532$ nm

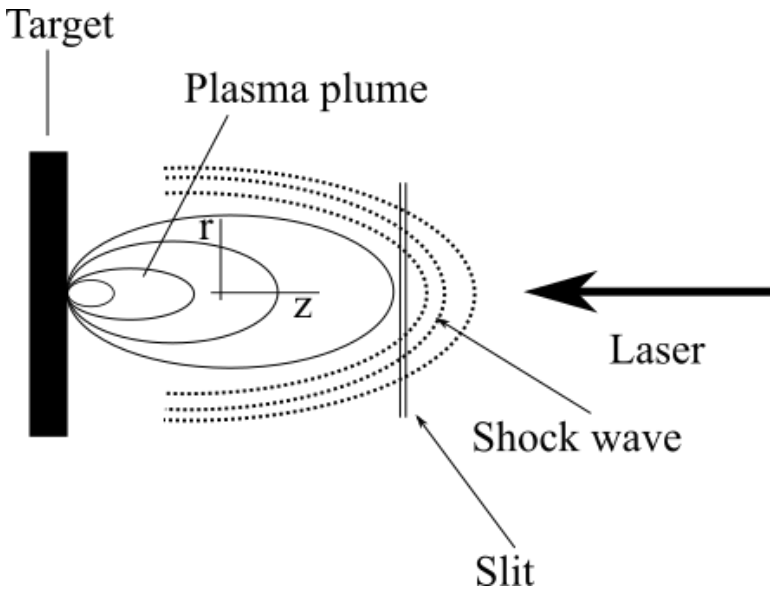
Instrumental profile
FWHM of 8.7 pm

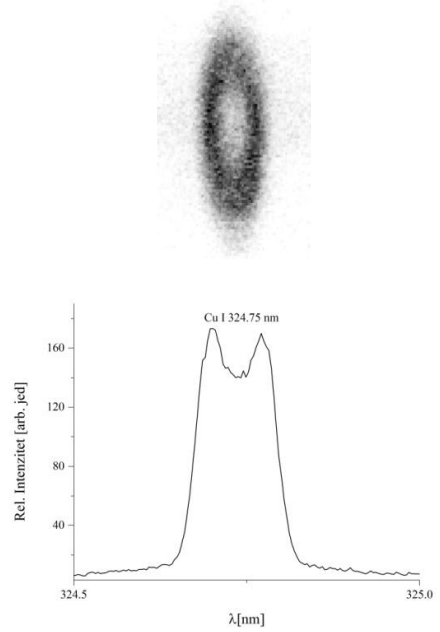
p = 20 Pa
$t \approx 1$ µs

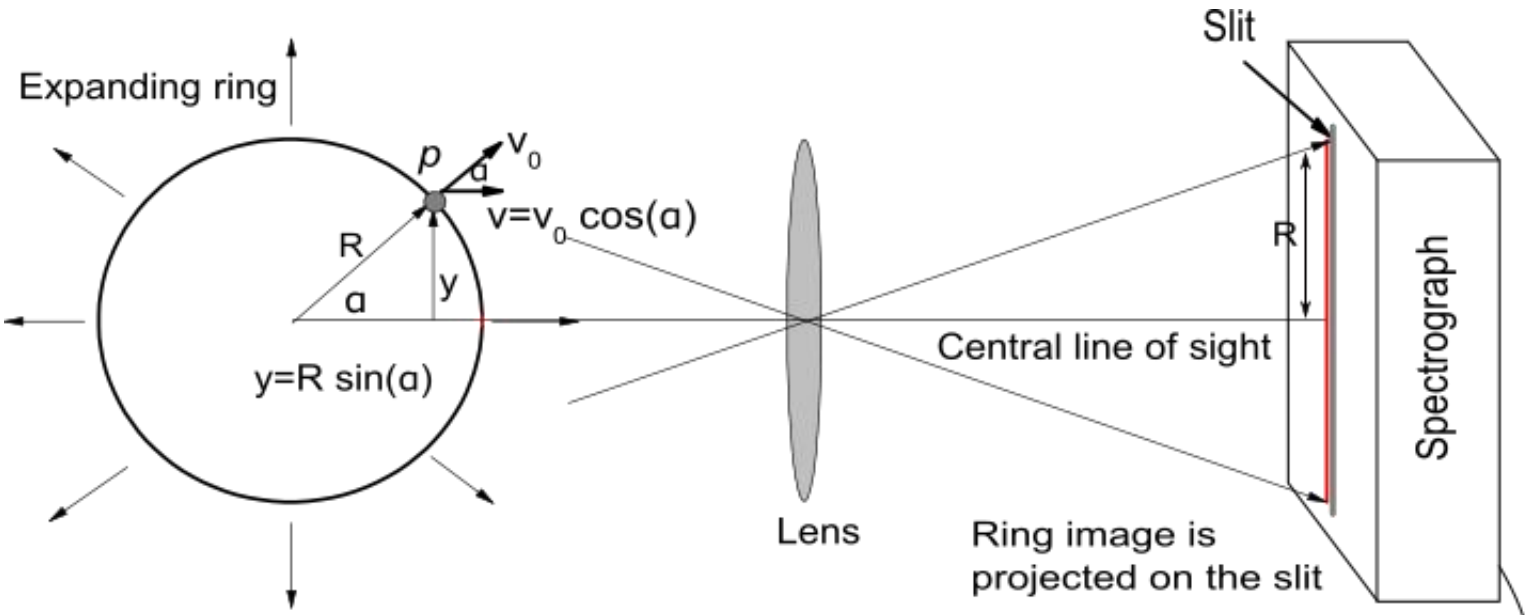

Target
Lens
Slit
ICCD
Spectrograph
Display
R
a
y
R
Central line of sight
Ring image is
projected on the slit
a)
b)
2.0x10^5
1.5x10^5
1.0x10^5
5.0x10^4
0.0
Rel. Int.
211.0
211.5
212.0
212.5
λ (nm)

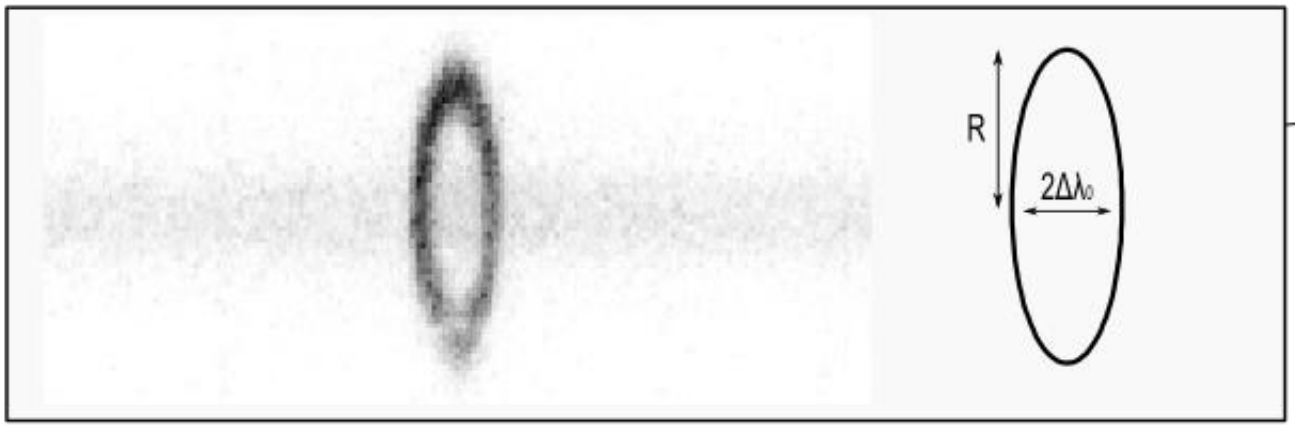

Target
Plasma plume
r
z
Laser
Shock wave
Slit


300
200
100
0
Rel. Intenzitet [arb. jed.]
324.6
324.7
324.8
324.9
λ[nm]


Target
Plasma plume
r
z
Laser
Shock wave
Slit


Cu I 324.75 nm
160
120
80
40
Rel. Intenzitet [arb. jed]
324.5
325.0
λ[nm]

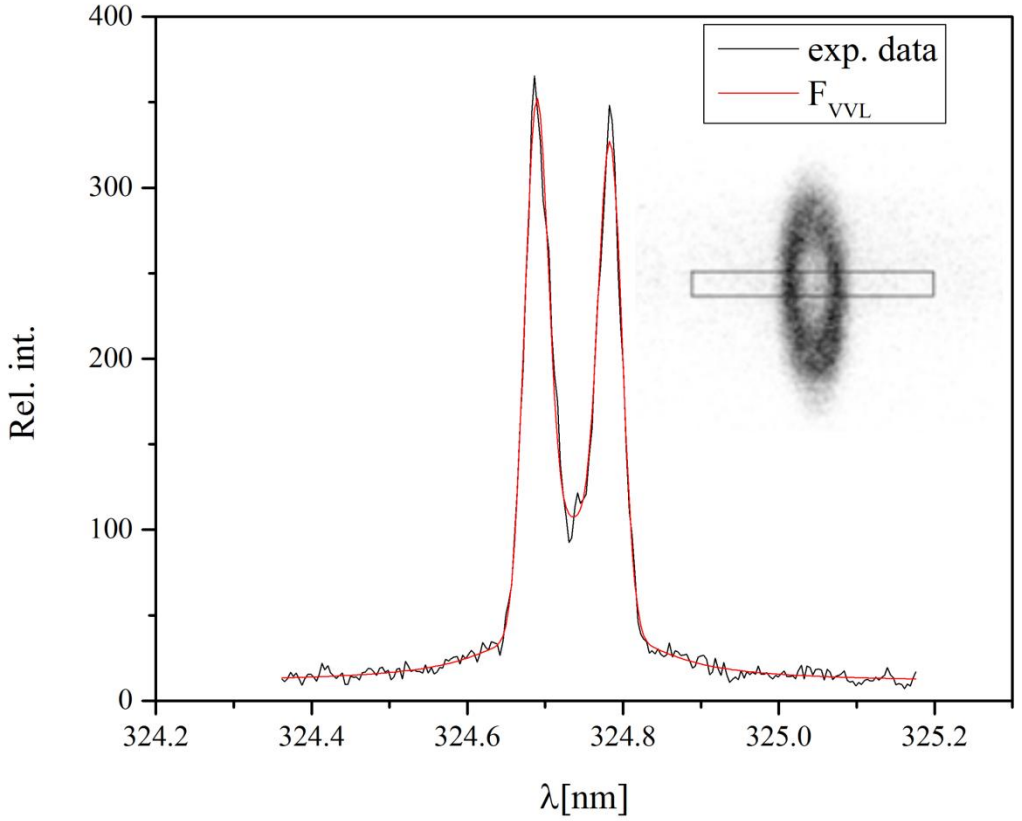




Measured profile

Analytic profile

$$\frac{c^2}{v_0^2}\left(\frac{\Delta\Lambda}{\lambda}\right)^2+\frac{y^2}{R^2}=1$$



- 324.75 nm Cu I resonant line
- z position: 2.75 mm from target
- t: 40 ns after the laser pulse

- Doppler broadening due to thermal motion of the particles
- Stark broadening

$$F_{VVL}(\lambda; a_1, \lambda_{c_1}, a_2, \lambda_{c_2}, \sigma, \gamma, a_3, w, b) = V(\lambda; a_1, \lambda_{c_1}, \sigma, \gamma) + V(\lambda; a_2, \lambda_{c_2}, \sigma, \gamma) + L(\lambda; a_3, w) + b$$

Modal function

Modal function $F_{VVL} \Rightarrow$ parameters $\lambda_{c_1}, \lambda_{c_2}, \sigma$ from experimental data

From pick separation

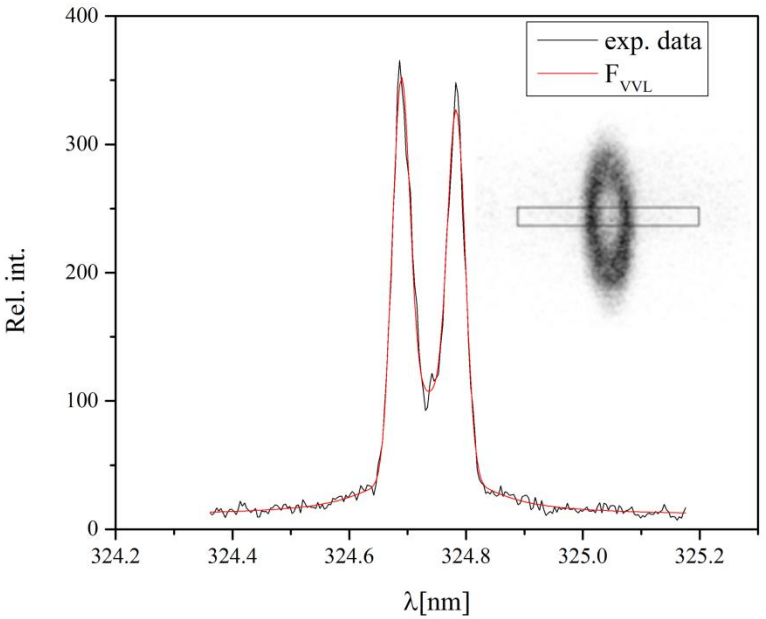
$$v_0 = \frac{c}{\lambda_c}\left(\lambda_{c_2} - \lambda_{c_1}\right)$$

$$v_0 = \left(43700 \pm 200\right) \text{m/s}$$

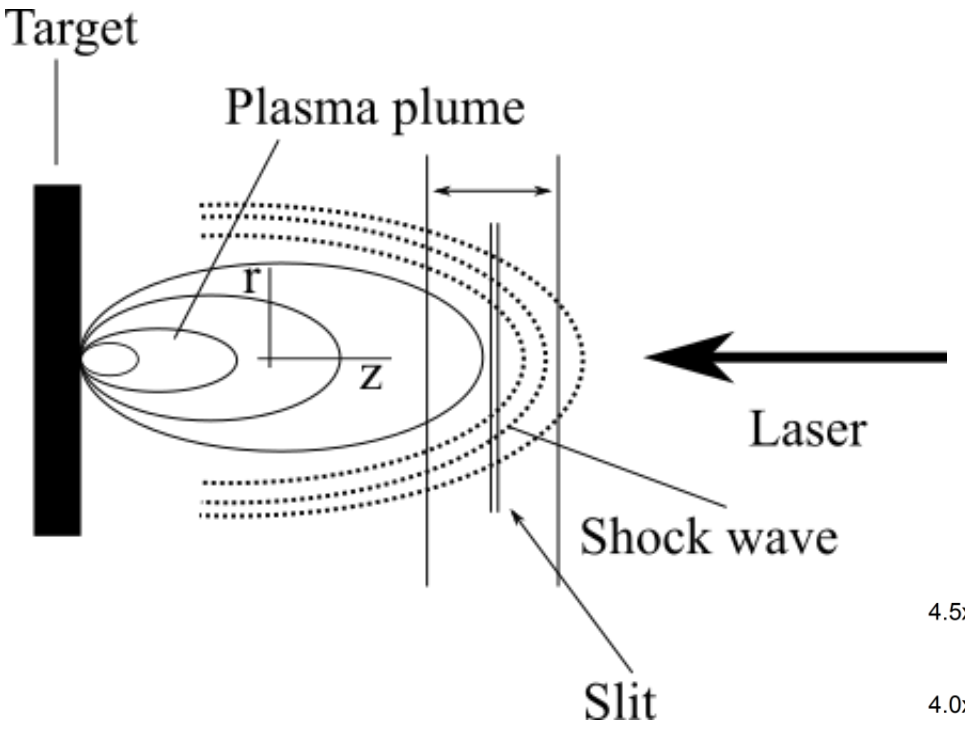
Temperature of the heavy particles:

$$T = \frac{mc^2\sigma^2}{8k_B \ln 2 \lambda^2}$$

$$T = \left(560 \pm 60\right) \cdot 10^3 \text{ K}$$

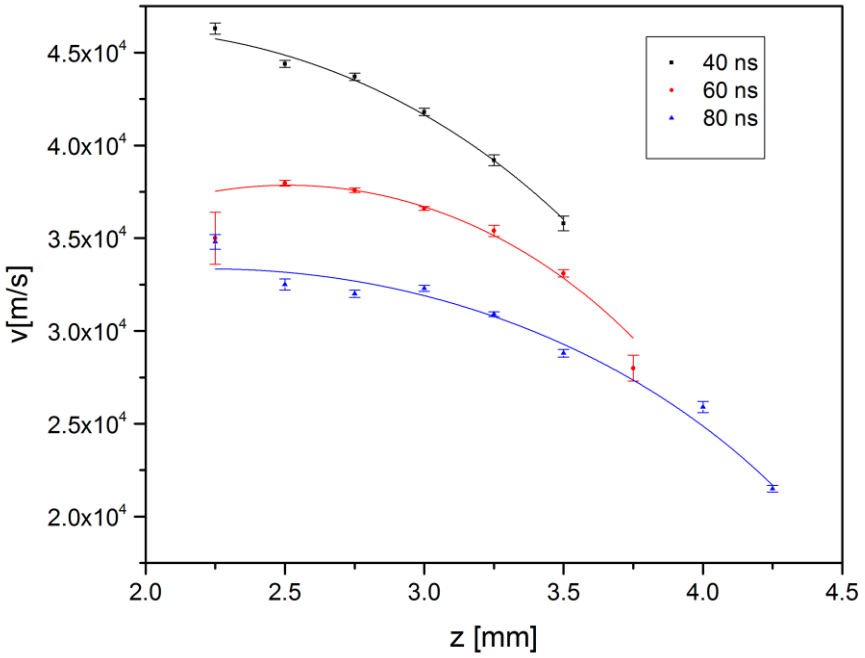


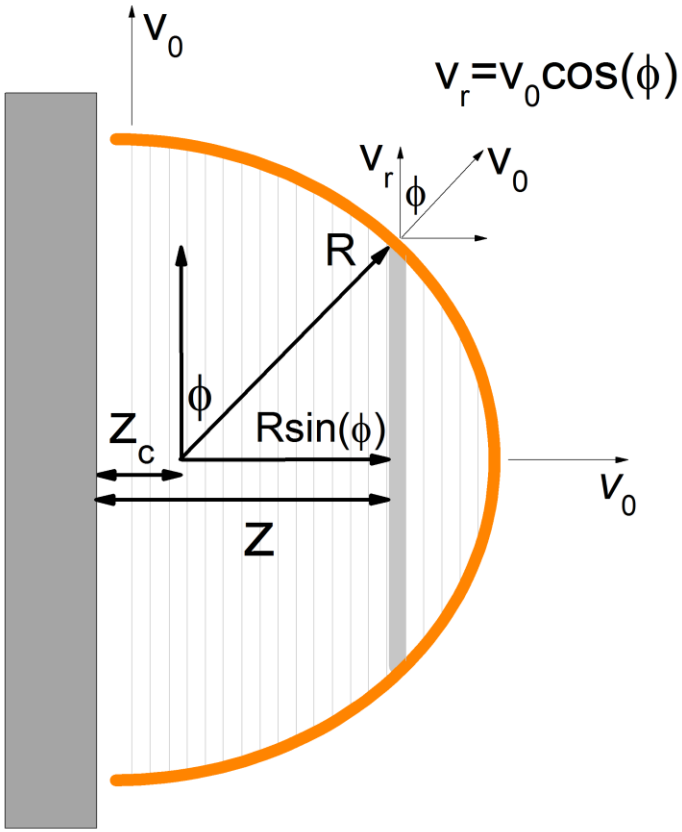
S. S. Harilal, C. V. Bindhu, M. S. Tillack, F. Najmabadi, and A.C. Gaeris, Internal structure and expansion dynamics of laser ablation plumes, J.App.Phys. (2003)



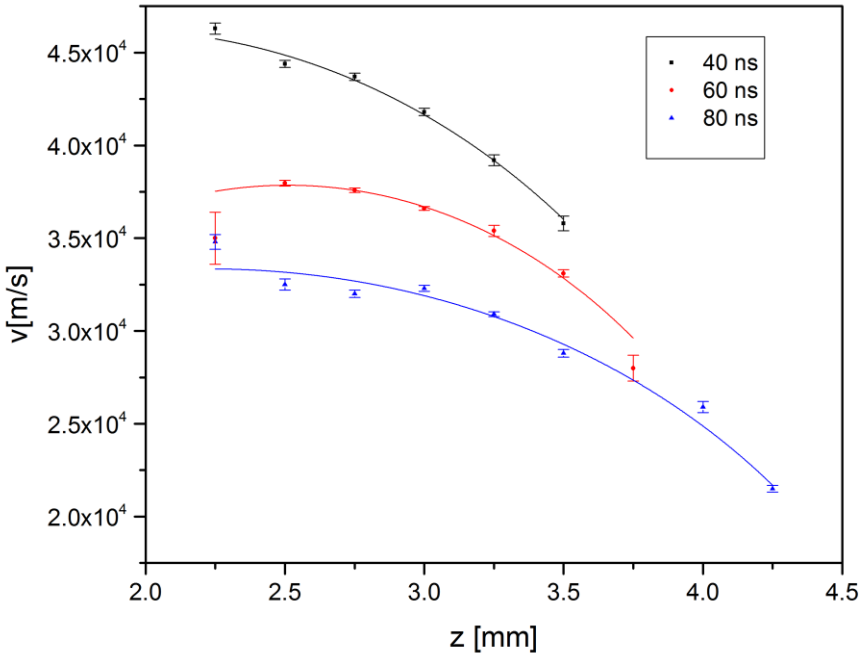
Cu I resonant line

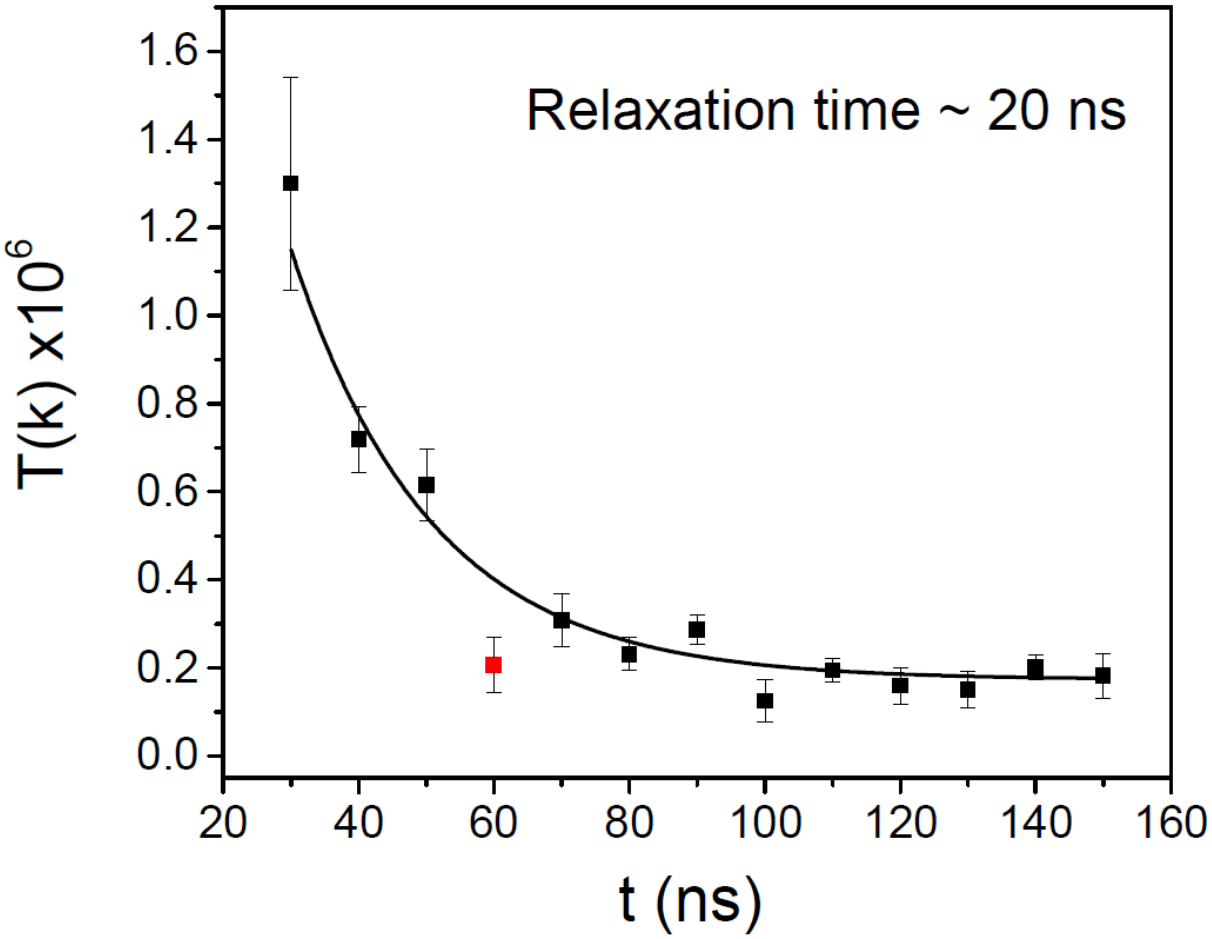
- *z* ranges from 2.25 mm to 4.25 mm
- *t* ranges from 40 ns to 80 ns





$$v = v_0 \sqrt{1 - \frac{(z - z_{cm})^2}{R^2}}$$




Relaxation time ~ 20 ns
T(k) x10^6
t (ns)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
20
40
60
80
100
120
140
160

•We considered laterally resolved spectra recorded in typical side-on measurement in LIBS experiment.

•We demonstrated that characteristic oval shape of the spectral lines is caused by Doppler effect due to fast radial expansion of the laser induced plasma.

•Relying on Doppler splitting of the Cu I 324.75 nm line we evaluated velocity and temperature of the heavy particles.

• It was found that 40 ns after the laser was triggered the expansion velocity and temperature are approximately 50 000 m/s and 500 000 K.

•Also, we evaluated haw expansion speed of the hot plasma front depends on spatial and temporal coordinates.

Group members:

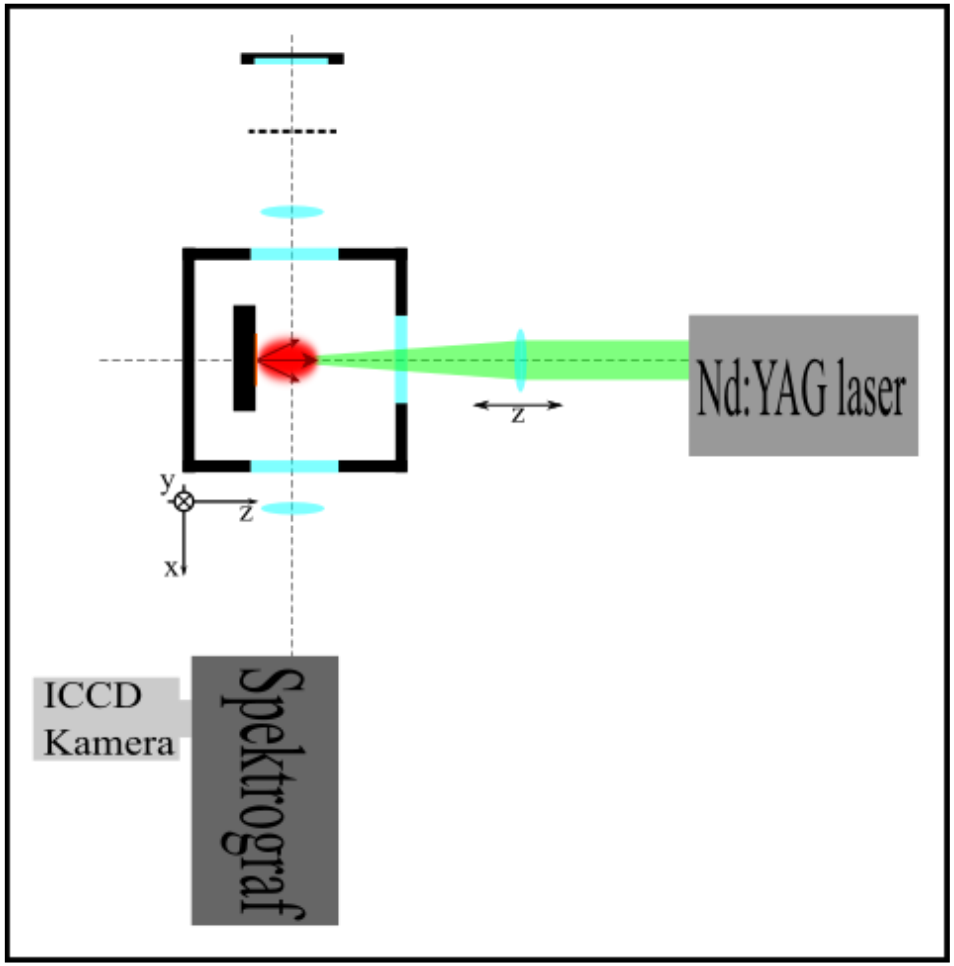
- Prof. Stevan Đeniže
- Prof. Srđan Bukvić
- Miloš Burger
- Miloš Skočić
- Dejan Dojić

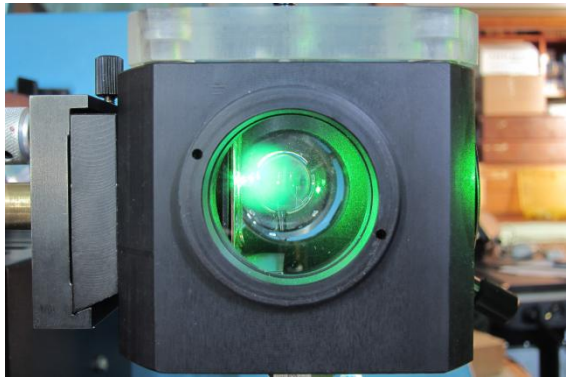
Acknowledgements:

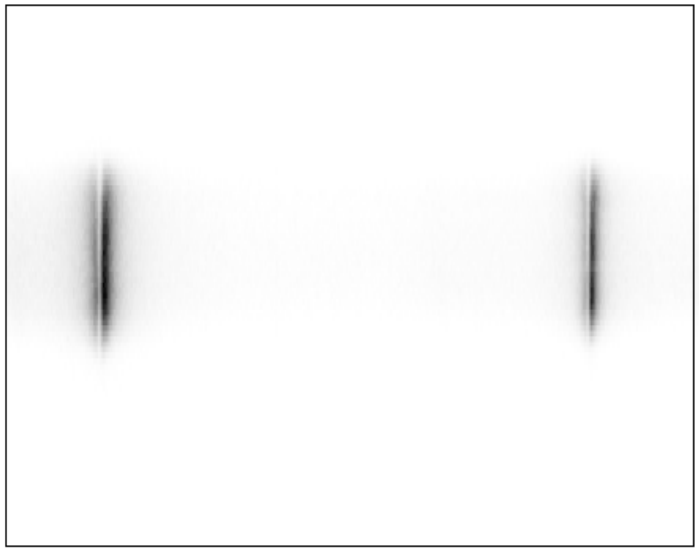
This work is part of the project "Determination of atomic parameters on the basis of spectral line profiles" (ON171008) supported by Ministry of Education and Science of the Republic of Serbia.

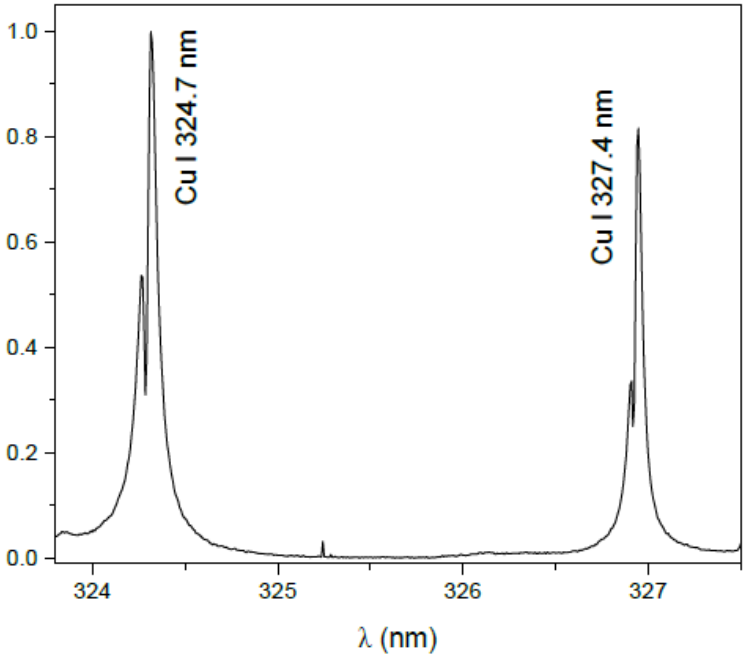
Thank you for your attention.

Postavka eksperimenta








1.0
0.8
0.6
0.4
0.2
0.0
Cu I 324.7 nm
Cu I 327.4 nm
324
325
326
327
λ (nm)