Beam diagnostics for plasma wake-field acceleration and betatron radiation.

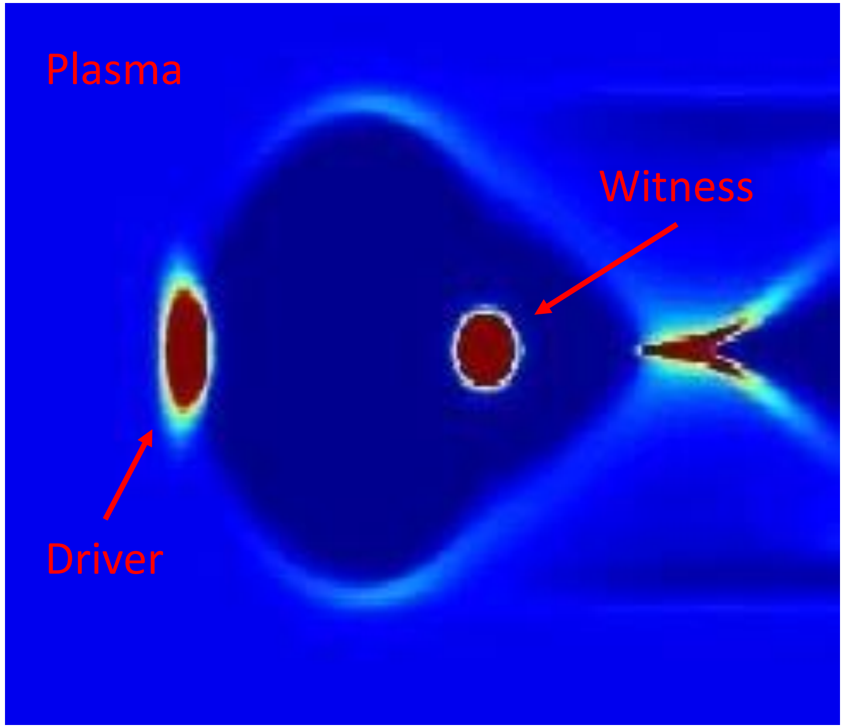
SPARC_LAB, Vladimir Shpakov

$$\lambda_p = 2\pi c\sqrt{\frac{m_e\epsilon_0}{n_p e^2}}$$

Plasma wavelength can vary from 100s down to 10s μm

$$\sigma_x = \sqrt[4]{\frac{2}{\gamma}}\sqrt{\frac{\epsilon_n}{k_p}}$$

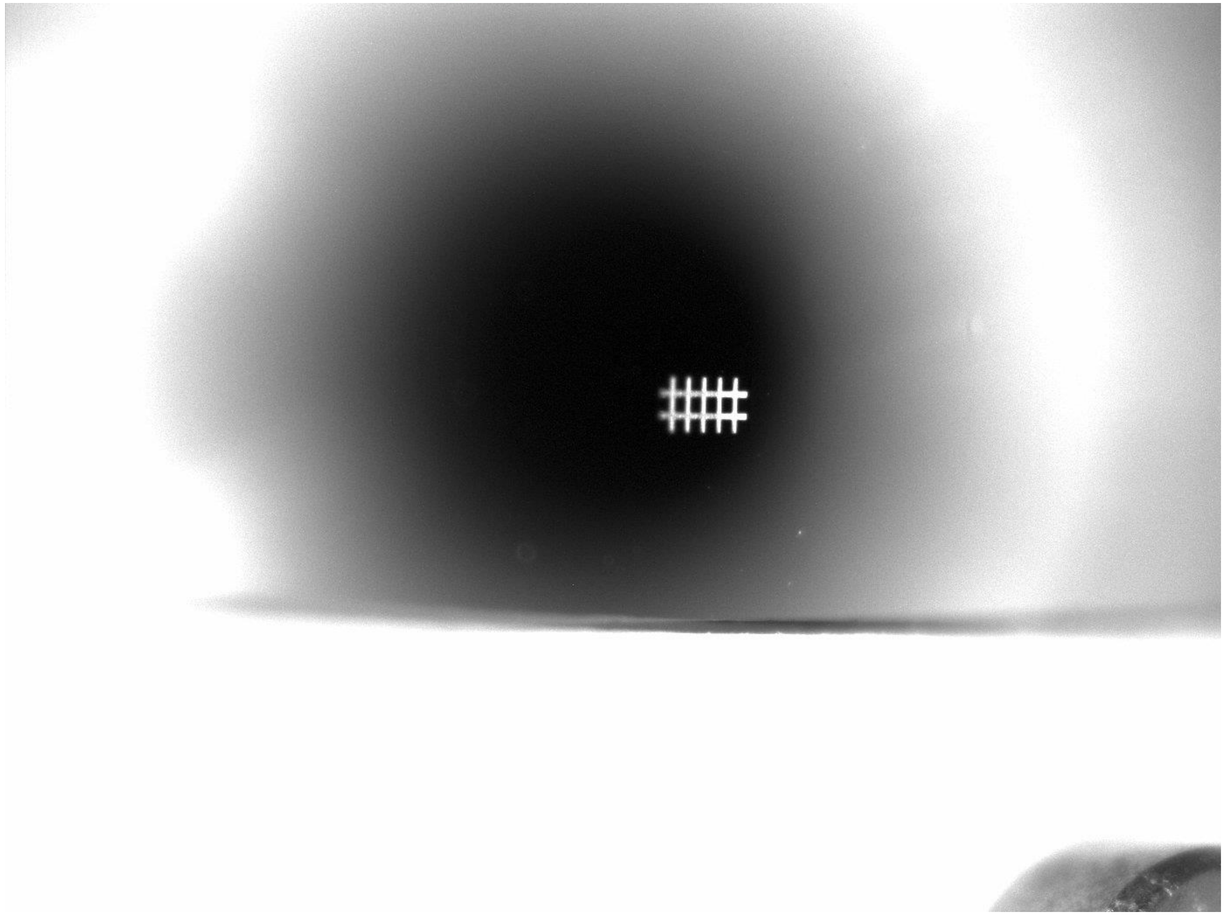
Matching conditions for the witness will give us the transverse size of the beam at injection at the submicron level.

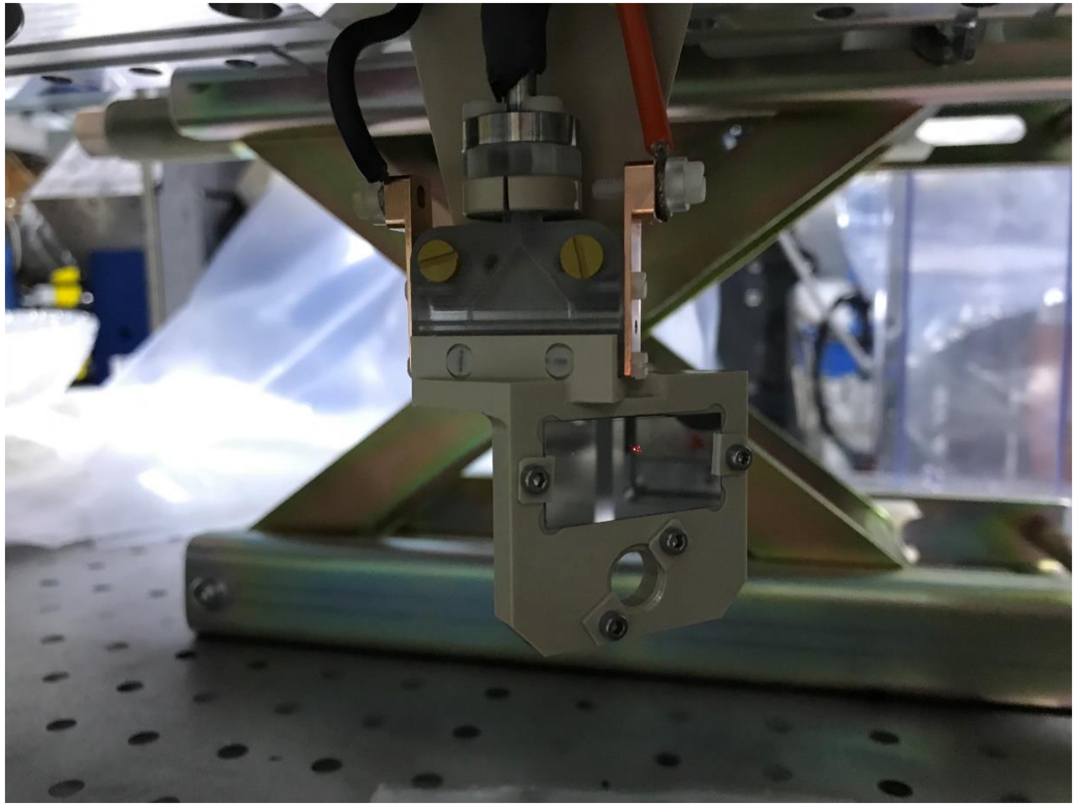


High brightness electron beams

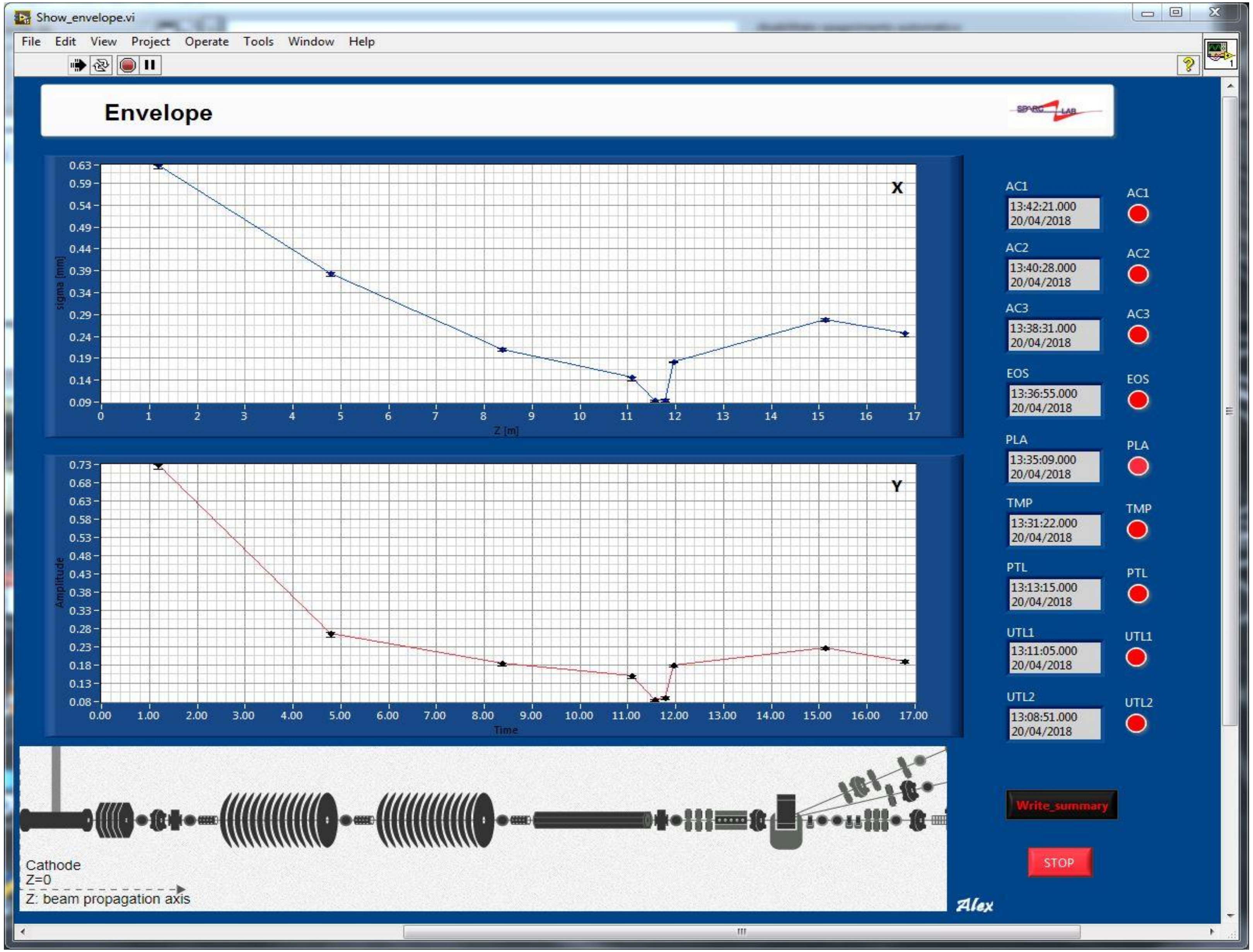
- high resolution
- saturation problems
- single shot measurements

in addition for PWFA – diagnostics with betatron radiation





- OTR screen
- YAG crystal 5 µm
- deepness of the focus


Show_envelope.vi
File Edit View Project Operate Tools Window Help
Envelope
X
sigma [mm]
Z [m]
Y
Amplitude
Time
AC1
13:42:21.000
20/04/2018
AC2
13:40:28.000
20/04/2018
AC3
13:38:31.000
20/04/2018
EOS
13:36:55.000
20/04/2018
PLA
13:35:09.000
20/04/2018
TMP
13:31:22.000
20/04/2018
PTL
13:13:15.000
20/04/2018
UTL1
13:11:05.000
20/04/2018
UTL2
13:08:51.000
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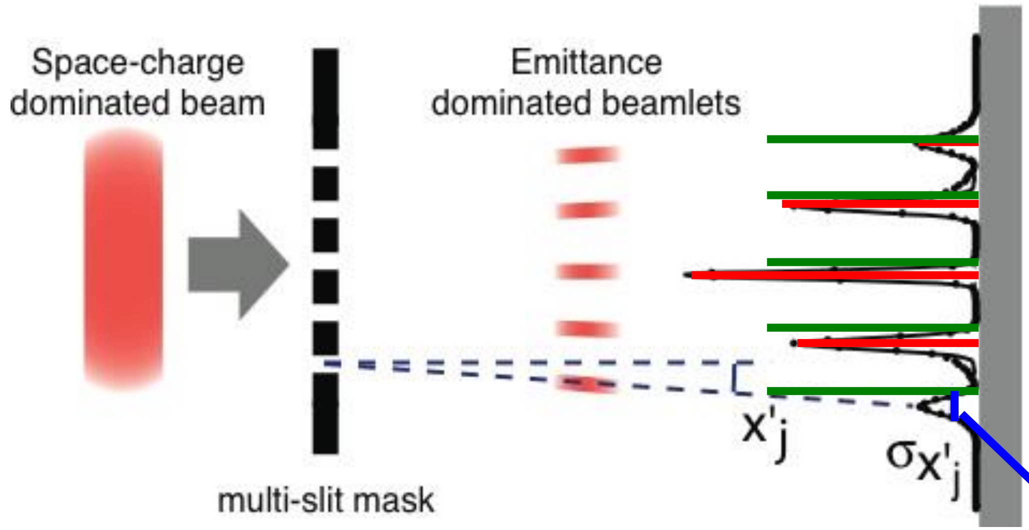
Write_summary
STOP
Cathode
Z=0
Z: beam propagation axis
Alex

transverse diagnostics, single shot

Pepper-pot method



In order to measure emittance we need three things:

- size
- divergence
- correlation factor

Pepper-pot method can provide all of this information in single shot, but not exactly suited for small beam due to mechanical issues.

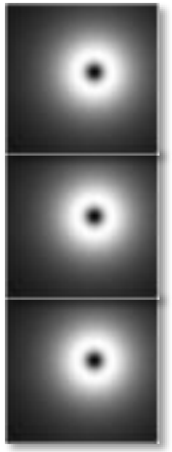
The alternative is optical pepper-pot based on transition radiation.

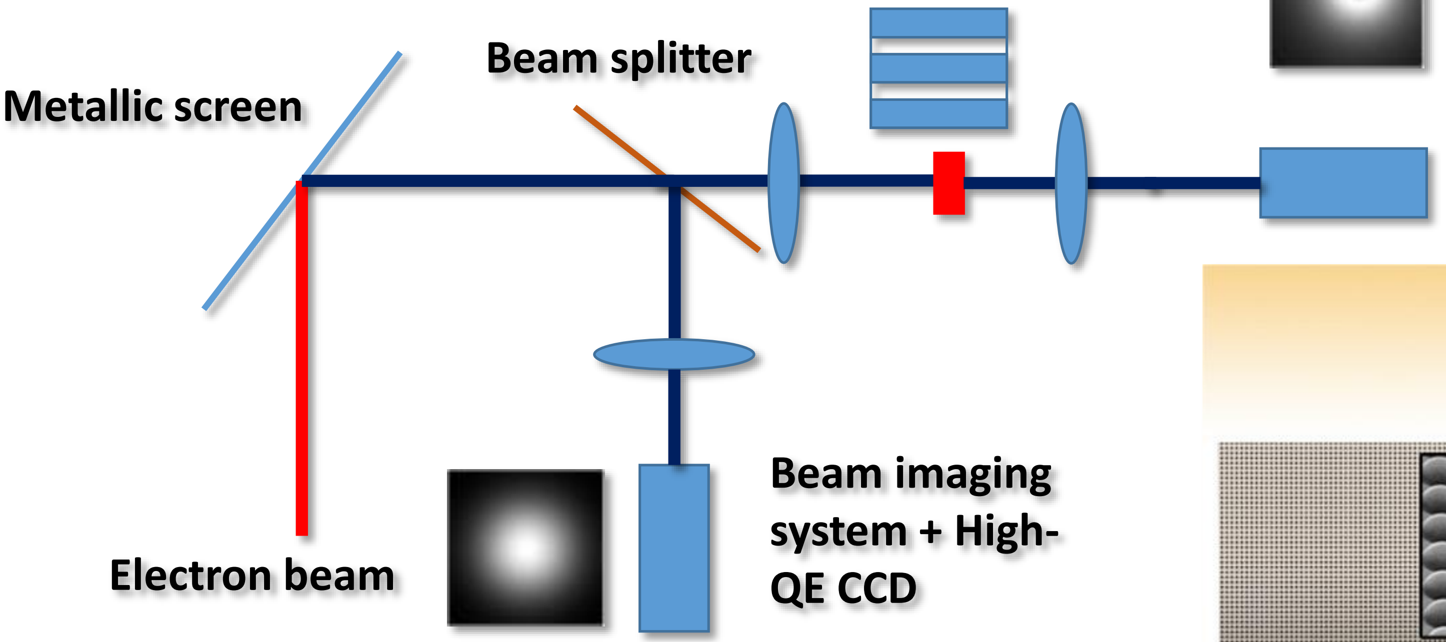
$$\varepsilon = \sqrt{< x^2 >< x'^2 > - < xx' >^2}$$

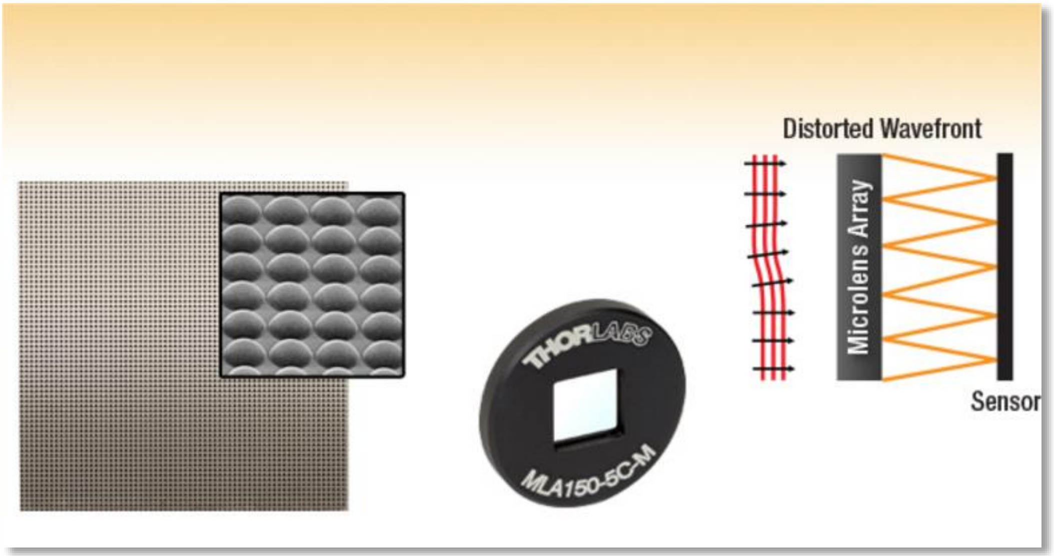
courtesy A.Cianchi

Angular distribution of OTR:

$$\frac{d^2U}{d\omega d\Omega} = \frac{e^2}{4\pi^3\varepsilon_0 c}\frac{\beta^2 \sin^2\vartheta}{(1-\beta^2\cos^2\vartheta)^2}$$







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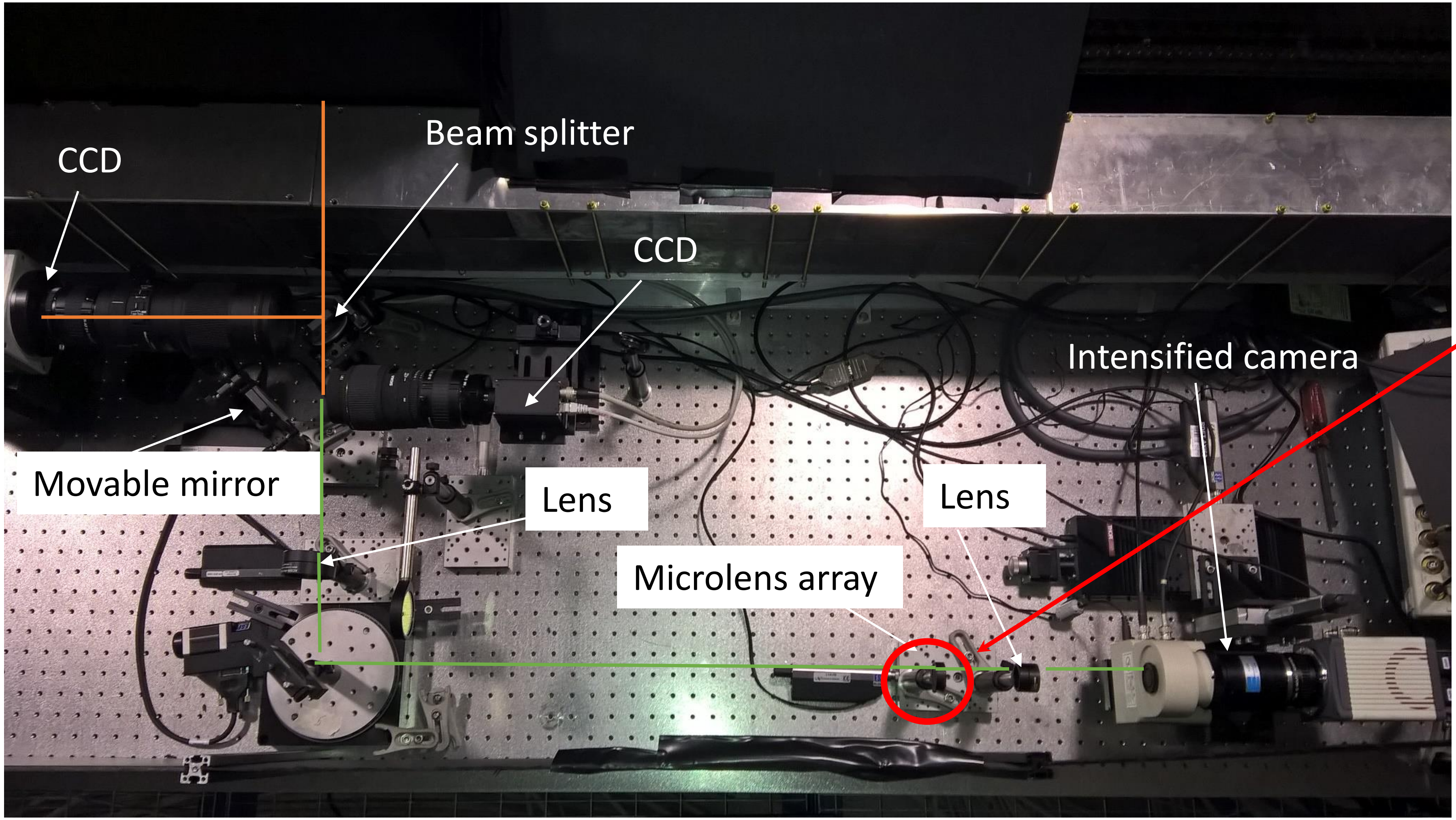
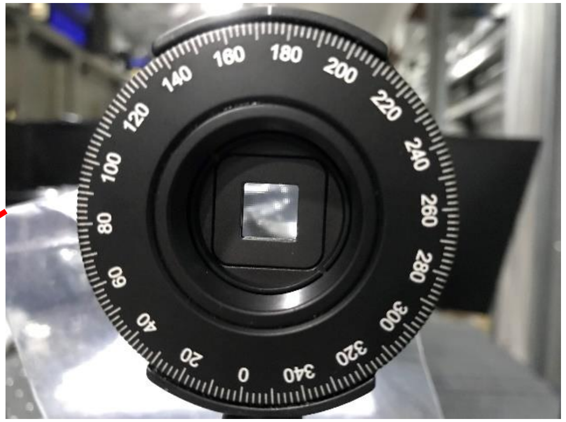
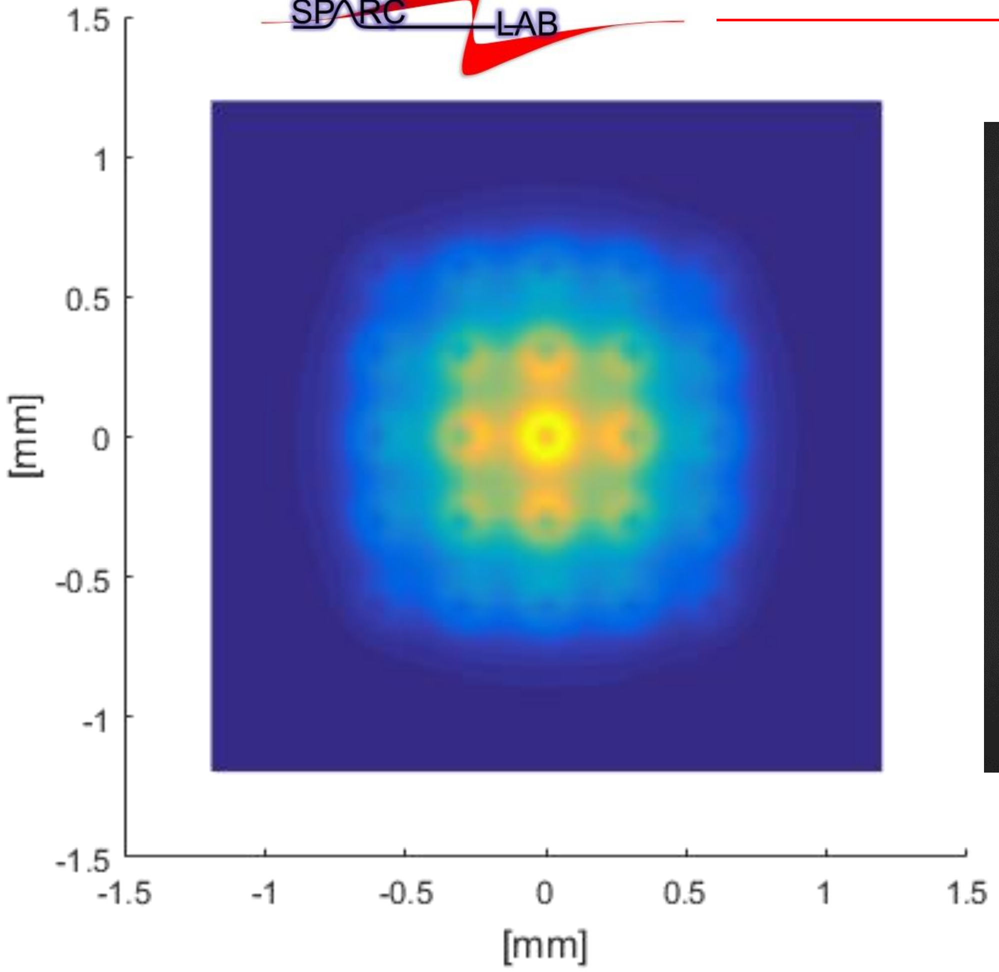
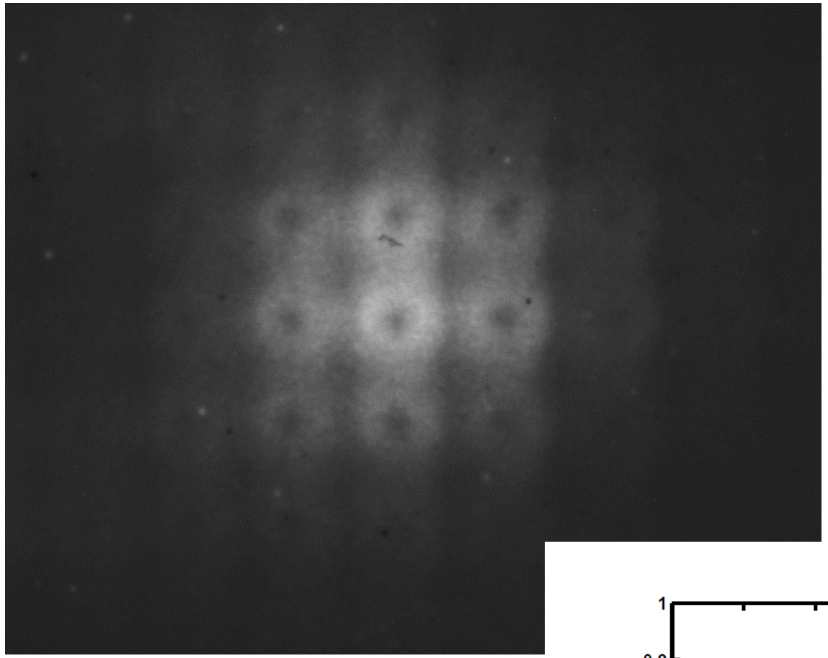
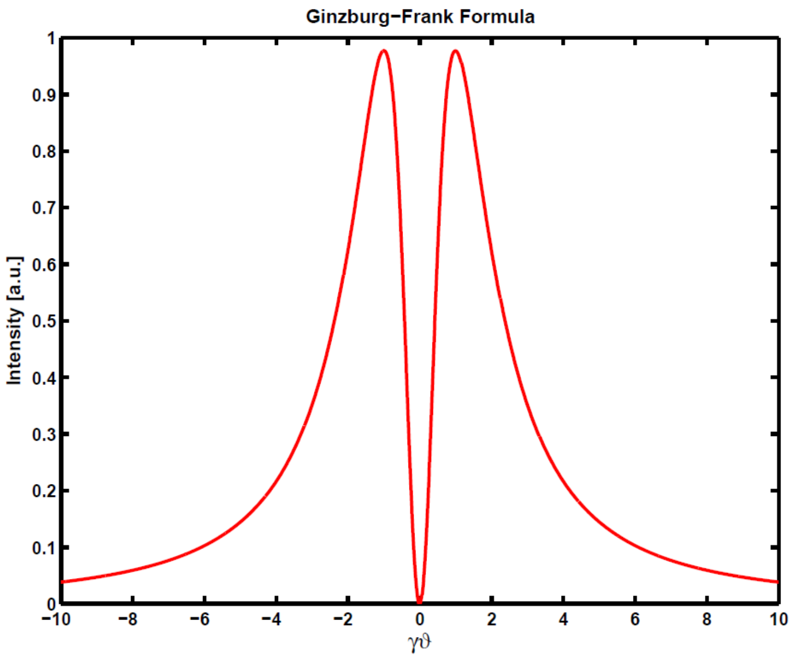


Micro-lenses array









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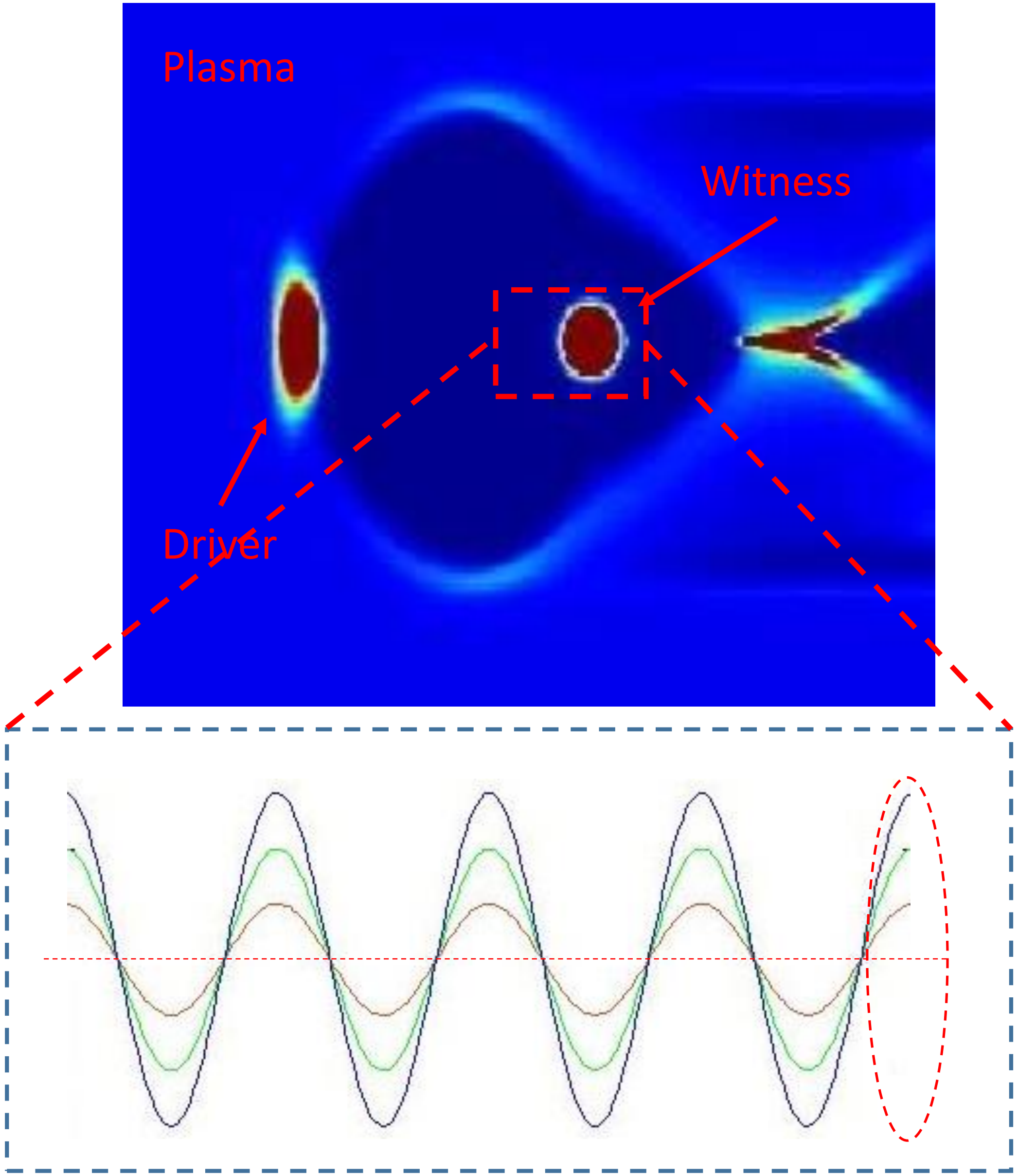
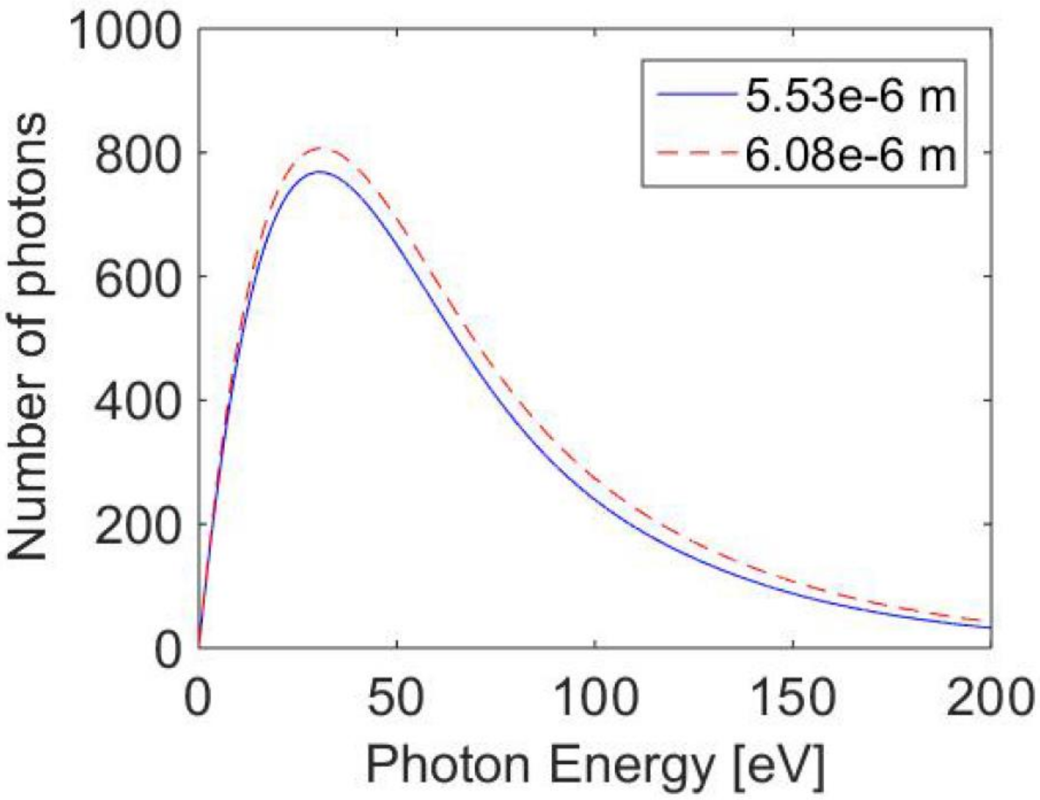
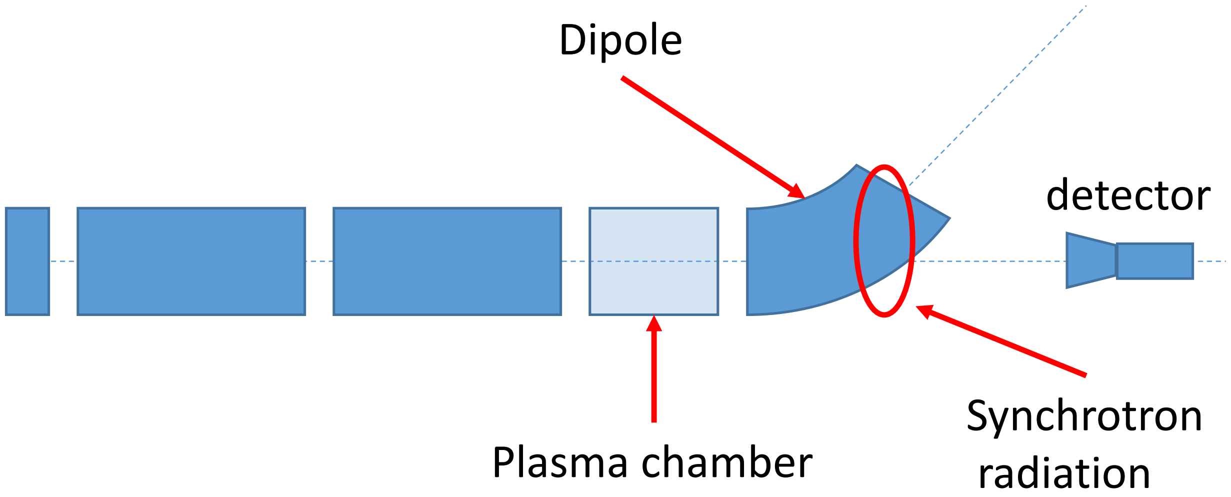
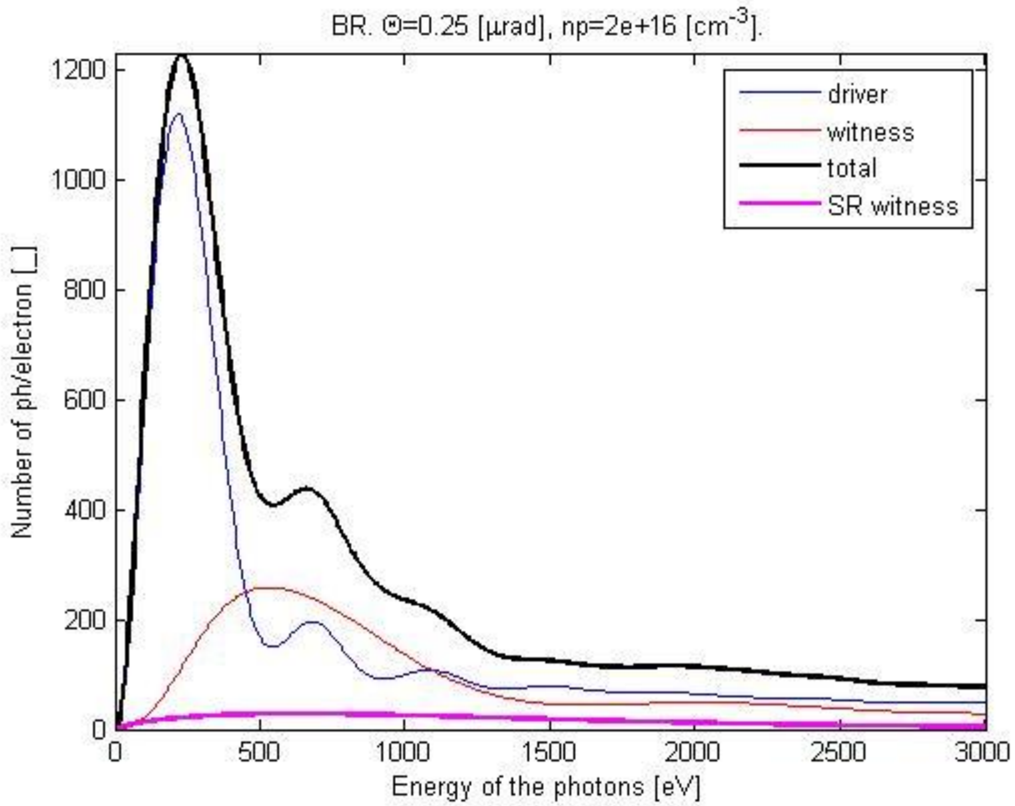


$$\frac{d^2 I_n(\omega,0)}{d\hbar\omega d\Omega} = \alpha_f \left(\frac{\omega}{\omega_n}\right)^2 \frac{\gamma_{z0}^2 N_\beta^2 n^2 a_\beta^2}{(1+a_\beta^2/2)^2} R_n(\omega,\omega_n)\left[J_{(n-1)/2}(\alpha_n) - J_{(n+1)/2}(\alpha_n)\right]^2$$

$$a_\beta = \gamma k_\beta r_\beta$$



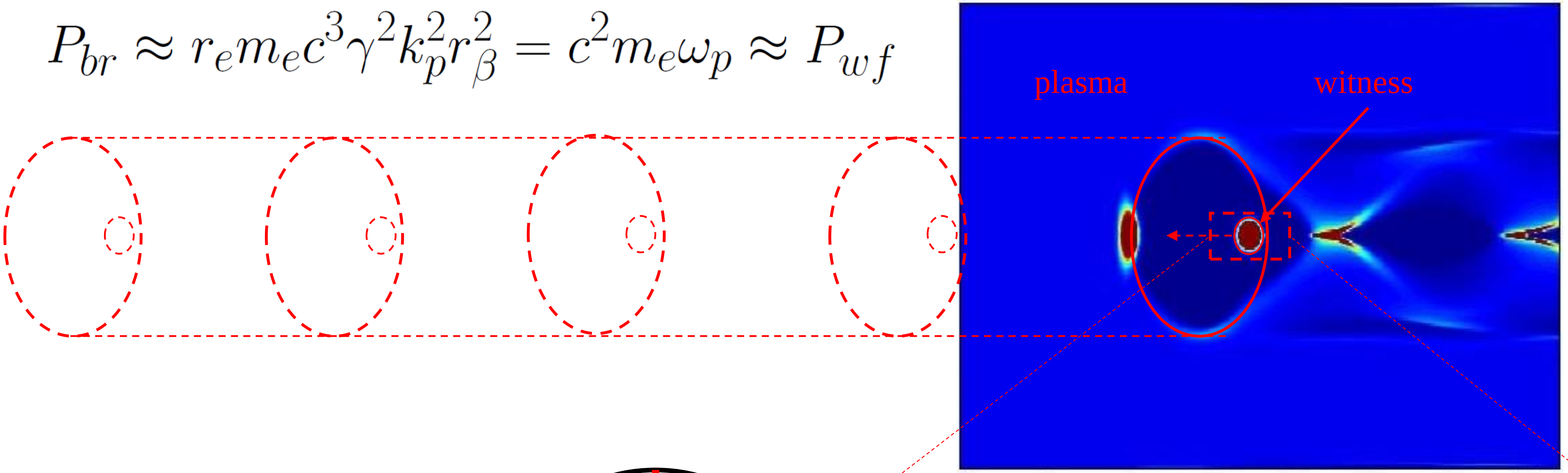




Betatron radiation can be used for beam diagnostics.
There are two main problems, though:

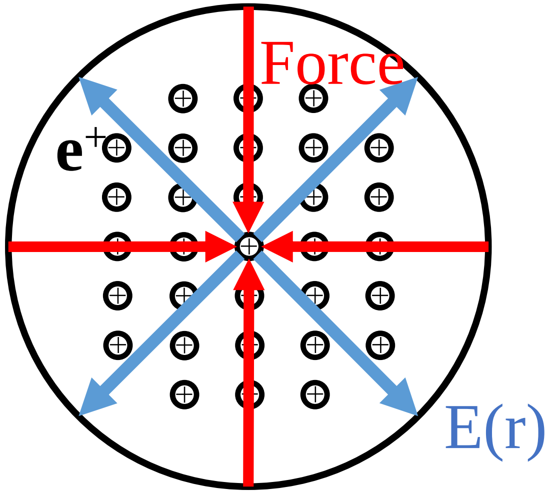
- we need to separate the witness and the BR flux, which inevitably leads to a synchrotron radiation from witness.
- in case of beam drive plasma acceleration we have to separate witness BR from the driver BR.

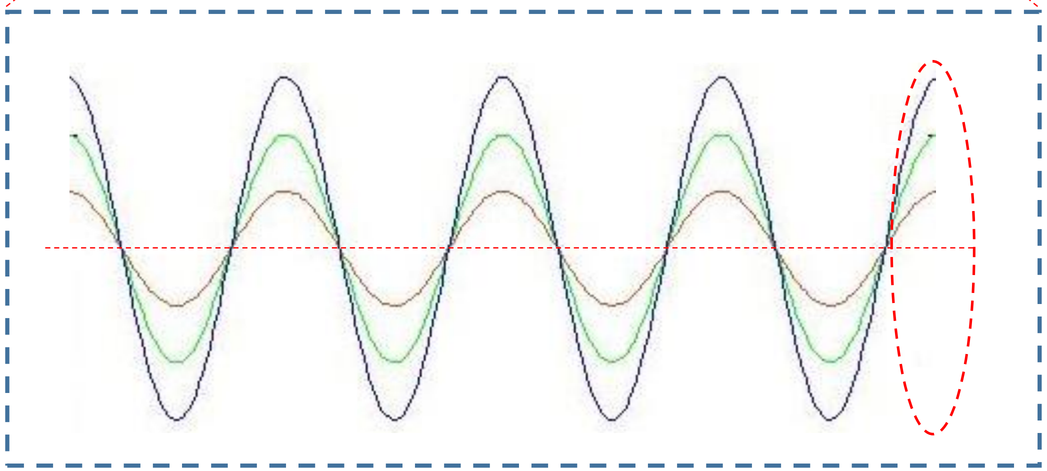
$$P_{br} \approx r_e m_e c^3 \gamma^2 k_p^2 r_\beta^2 = c^2 m_e \omega_p \approx P_{wf}$$



What we need to take into account:

- losses due to BR
- focusing of the beam
- cooling of the beam
- energy spread generation

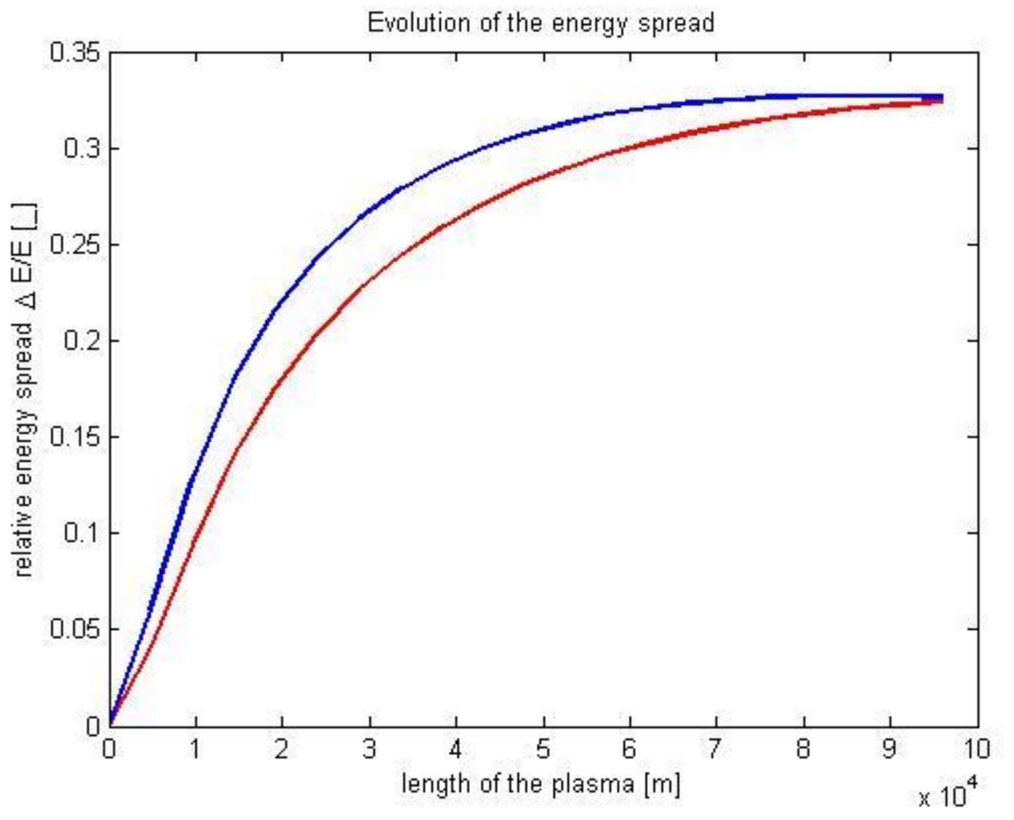


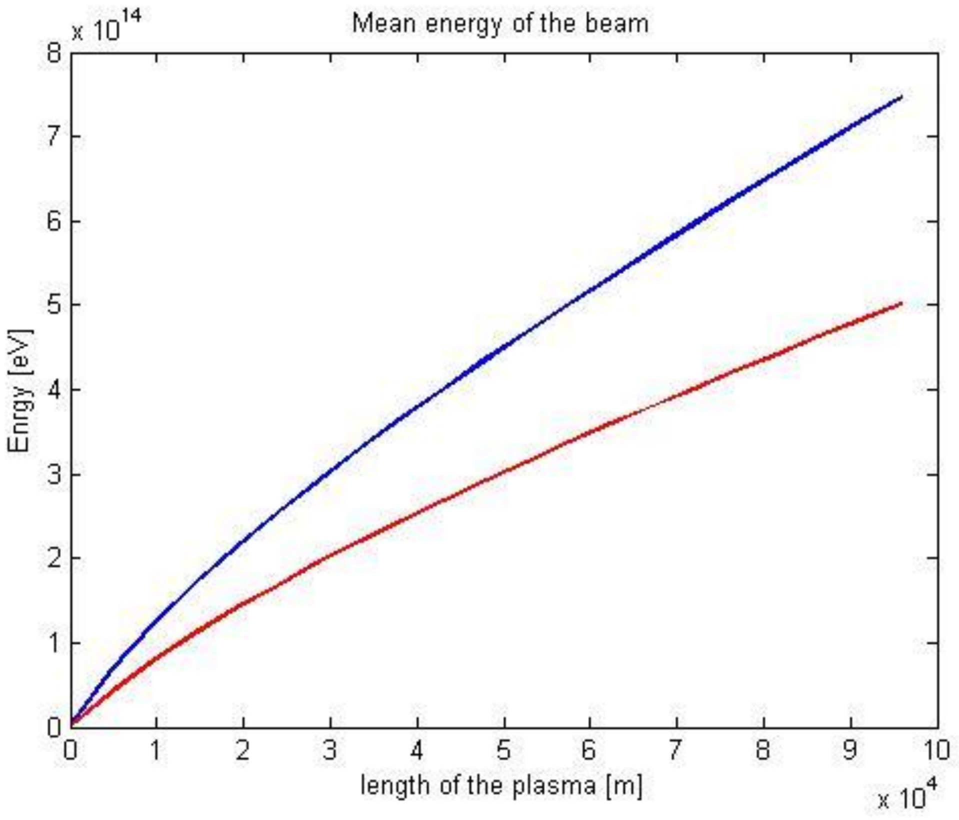


limit of the acceleration

$$\frac{d^2x}{dz^2} + \left(\frac{k_p^2}{\pi\gamma}z + \frac{e^2}{12\pi\epsilon_0 m_e c^2}k_p^2\right)\frac{dx}{dz} + \frac{k_p^2}{2\gamma}x = 0$$

$$\frac{d\gamma}{dz} = \frac{k_p^2}{\pi}z - \frac{e^2}{24\pi\epsilon_0 m_e c^2}k_p^4\gamma^4 x^2$$





Thank You!