Plasma Wakefield Accelerators for High-Brightness Beams.

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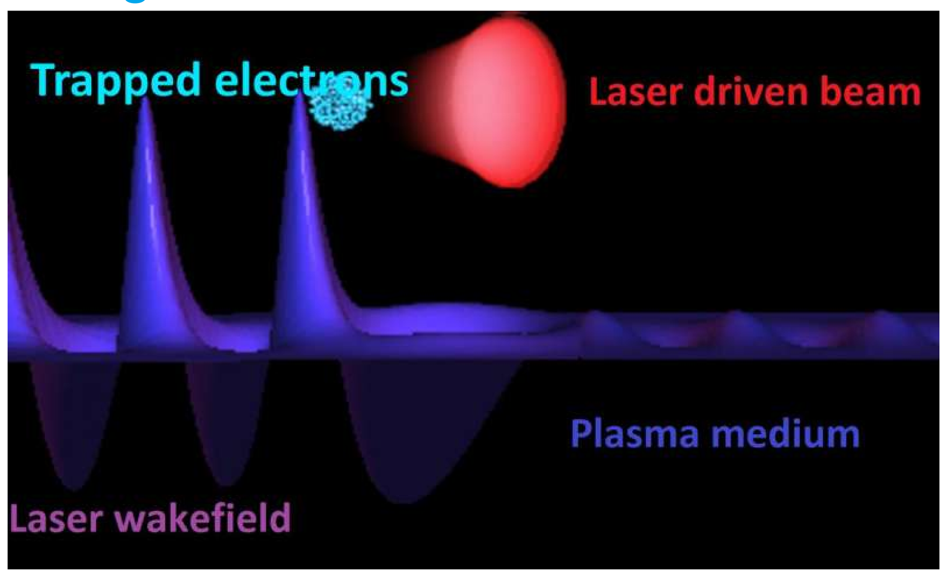
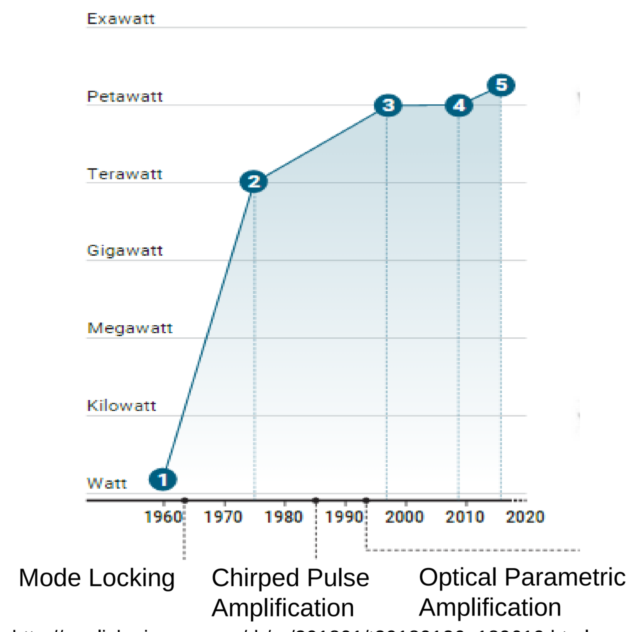
1. Plasma eyepiece for petawatt lasers

Background

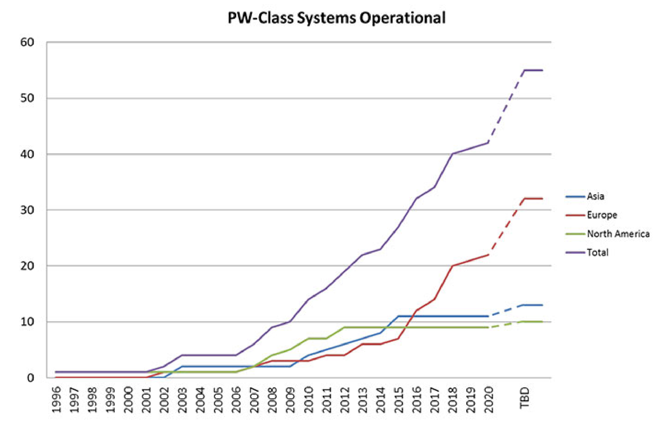


https://phys.org/news/2016-04-eupraxia-world-first-plasma-facility-strong.html
(Credit: The Cockcroft Institute, University of Liverpool)

- Laser wakefield acceleration (LWFA), introduced in 1979, is experiencing remarkable progresses.
- LWFAs usually require a moderate laser amplitude (a_0 < 5). Thus, for a petawatt-level laser beam, the focal length can be long (for a 1 PW laser, f ~ 10 m, while for a 100 PW laser, f ~ 1000 m).
- A flexible way for changing the laser spot size without replacing the focusing system, and reduction of the focal length for extreme powers is of great interest.

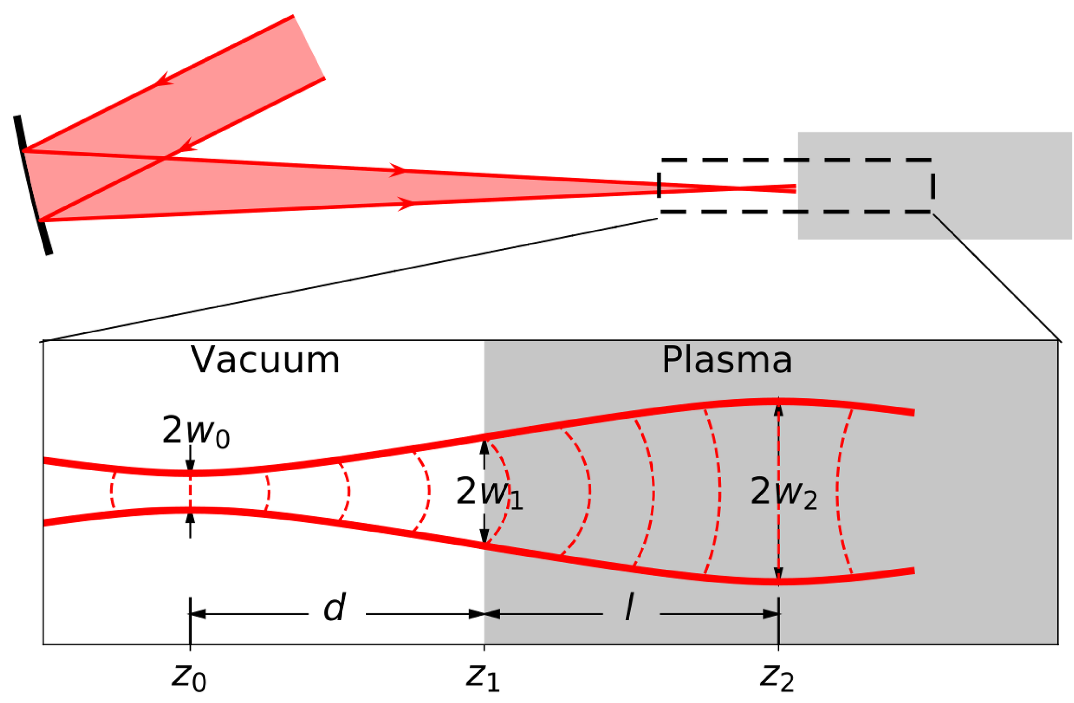


http://english.siom.cas.cn/rh/rp/201801/t20180126_189619.html
(Credit: C. Bickel / Science)



https://www.aip.org/fyi/2017/national-academies-study-aims-rally-us-research-high-intensity-lasers
(Credit: John Collier, courtesy of the National Academies)

Our scheme (telescope system)

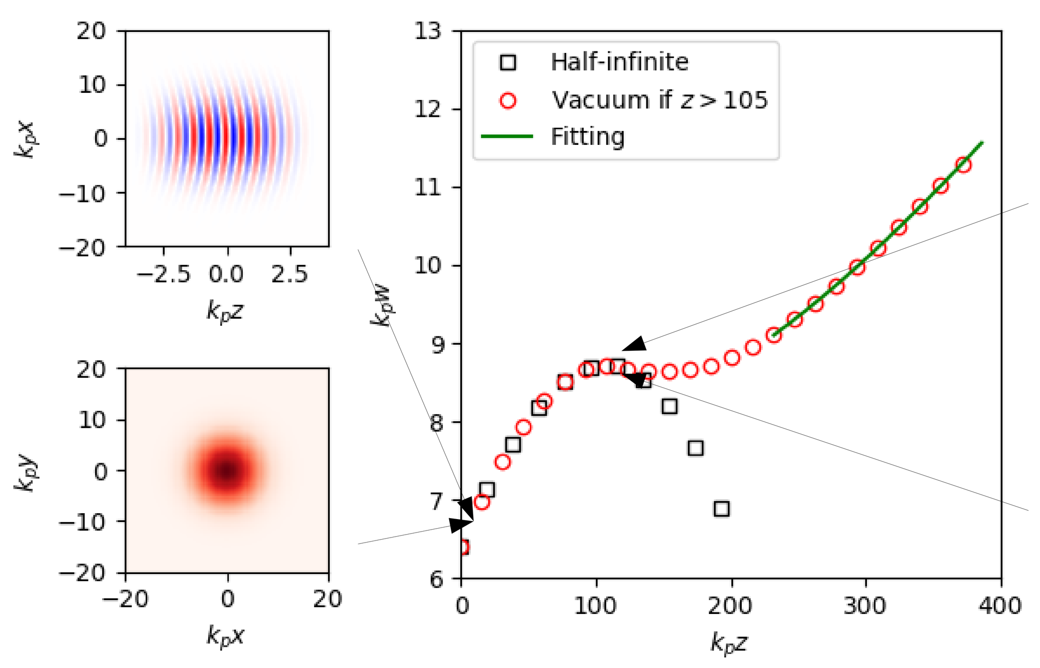


[Physics of Plasmas **27**, 023109 (2020)]

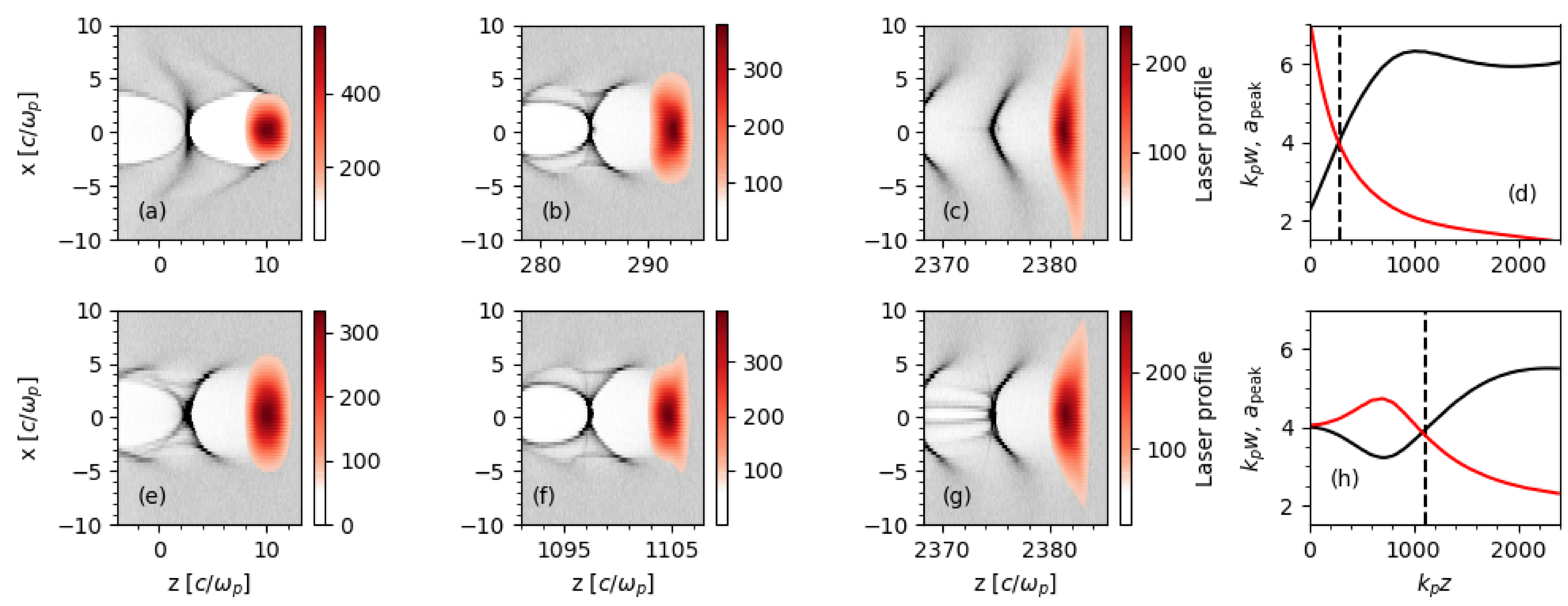
Results from simulations

$$\frac{w_2}{w_0}=\sqrt{1+\frac{d^2}{\zeta^2}},\quad \zeta \approx 0.95 z_R - 1.2k - 13. \qquad l \approx 21.0\frac{d}{w_0^{2.08}}.$$

Resizing of laser beam in plasma



Comparision simulations with or without plasma eyepiece



Conclusions

- Plasma acting as an adjustable eyepiece in a telescope system can effectively resize the petawatt laser beams.
- For the same effective focal spot size, the focal length can be largely reduced by using a plasma eyepiece.
- Such telescope system is easy to implement and can be widely adopted in the petawatt laser projects worldwide.

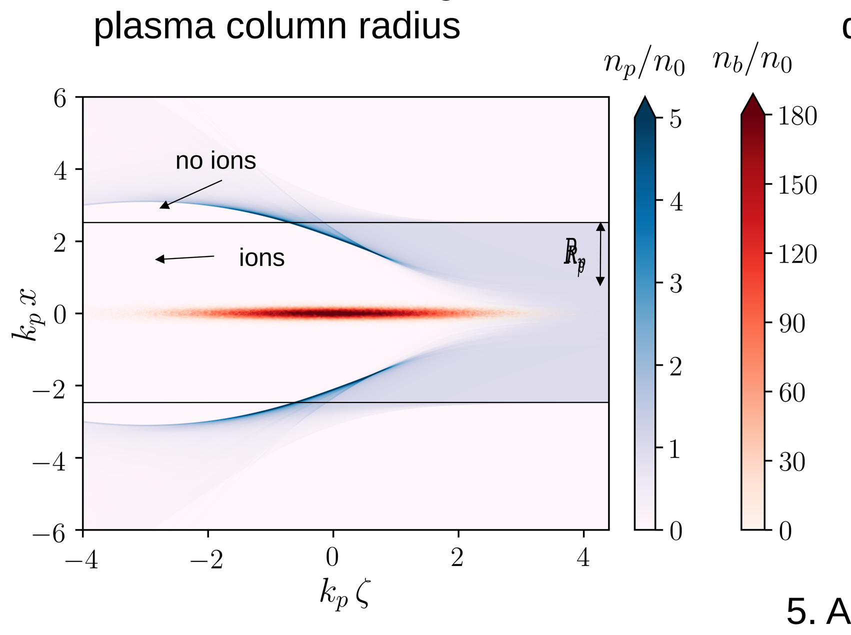
2. Positron acceleration in beam-driven plasma accelerators using plasma columns

- Due to the charge asymmetry, positron acceleration is challenging in plasma wakefield acceleration.
- A linear collider requires high-charge, low-emittance, low-energy-spread beams with a high accelerating gradient.
- No concept fulfills all the requirements so far.

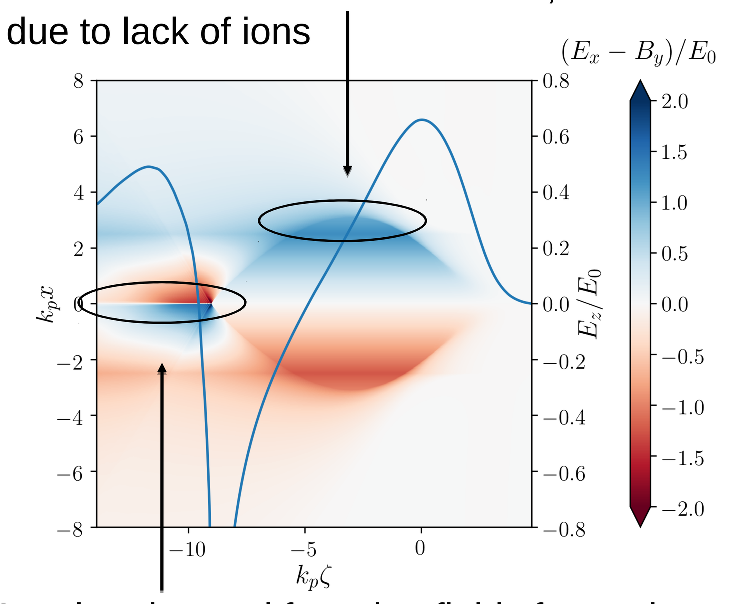
Key result Using a plasma column instead of a homogenous plasma, allows for efficient and emittance-preserving positron acceleration.

Future plans Techniques to maintain a low energy-spread and a stability analysis of the concept are currently under investigation.

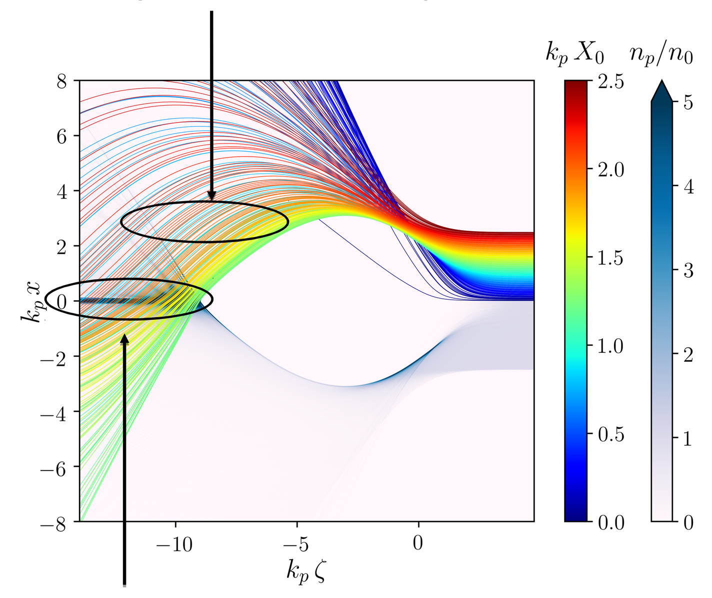
1. Blowout radius larger than plasma column radius



2. Modified transverse wakefield, due to lack of ions



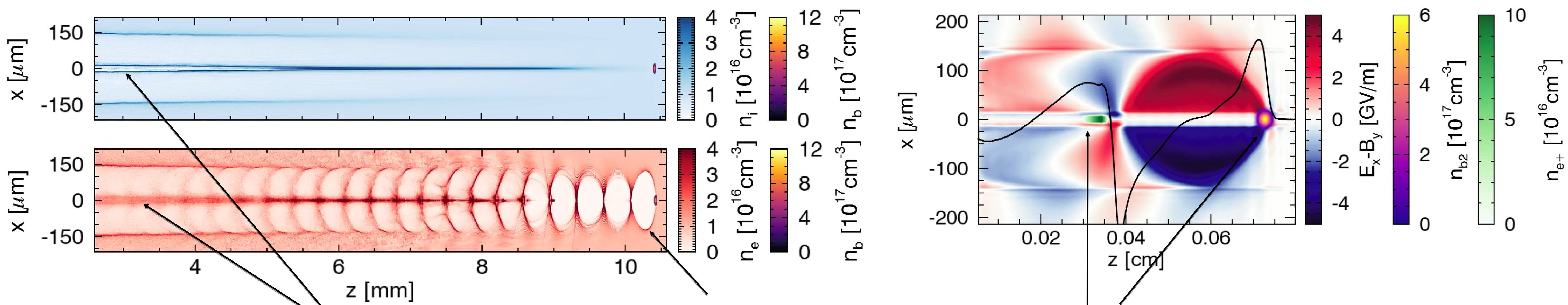
3. Elongated electron trajectories



5. Accelerating and focusing fields for positrons

4. Long, high-density electron filament

3. Positron acceleration using quasi-hollow channels generated by the plasma dynamics in the trail of the blowout



1) Blowout regime driven by electron beam

2) Generation of a quasi-hollow channel with on-axis structures

3) Second driver at the the appropriate time-delay from the first

4) Positron beam in a region of accelerating and focusing fields

- Main drawback of perfect hollow plasma channels: beam breakup instabilities ruin the beam before any significant acceleration.
- Another novel configuration is studied for positron acceleration: quasi-hollow channels generated in the trail of the blowout regime.
- We demonstrated stable and quality acceleration over 30cm propagation with no significant beam breakup.