Direct laser acceleration with radially polarized long-wave infrared lasers

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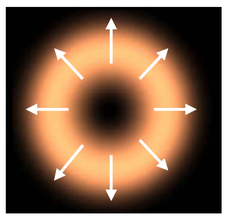
Radially polarized beams

Radially polarized beams are defined by their spatially dependent polarization.
One major difference between radially polarized beams and linearly polarized beams is the strong longitudinal field at the focus.



Example of a radially polarized beam[1]

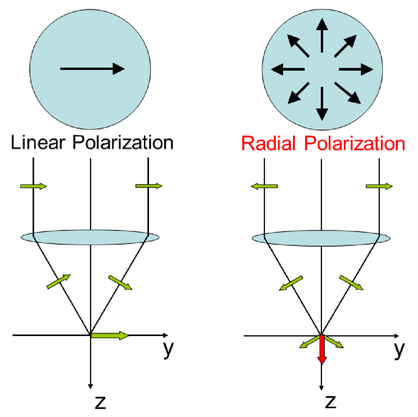
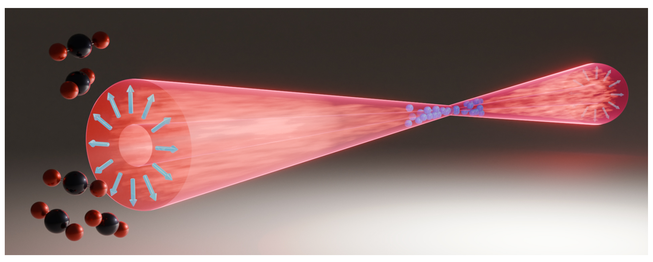
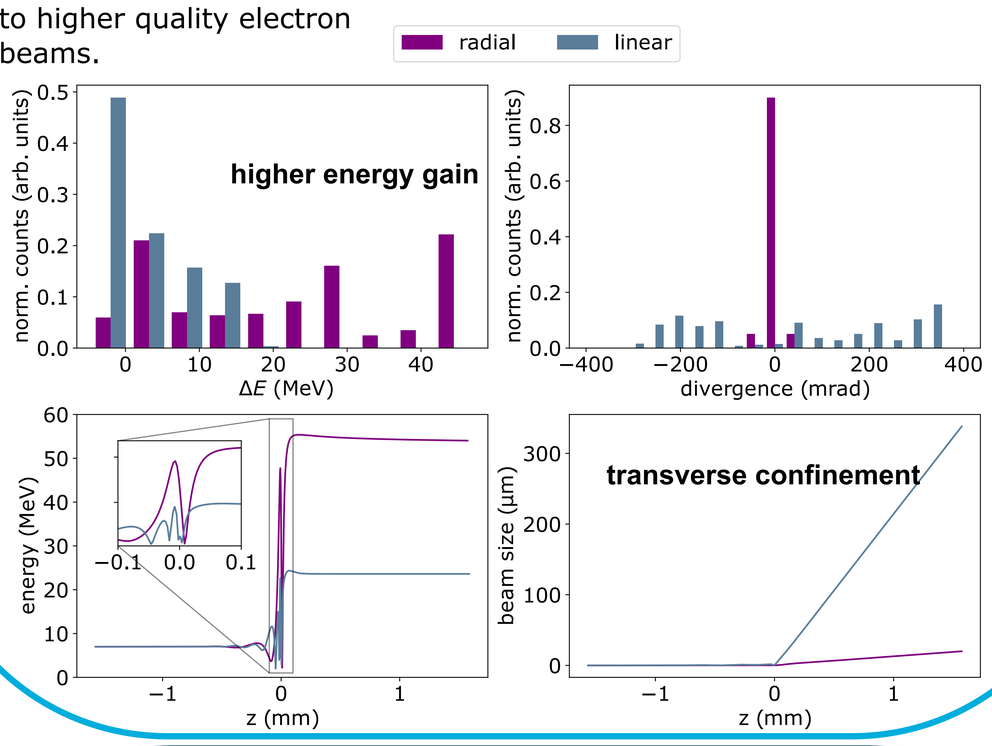


Illustration of longitudinal field at focus[2]

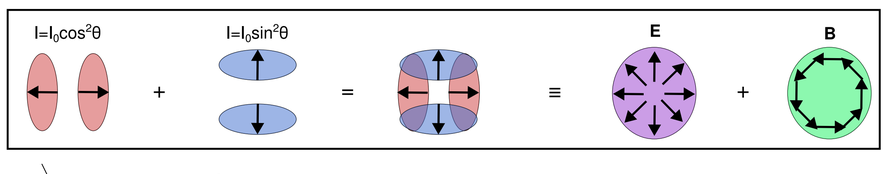
Direct laser acceleration

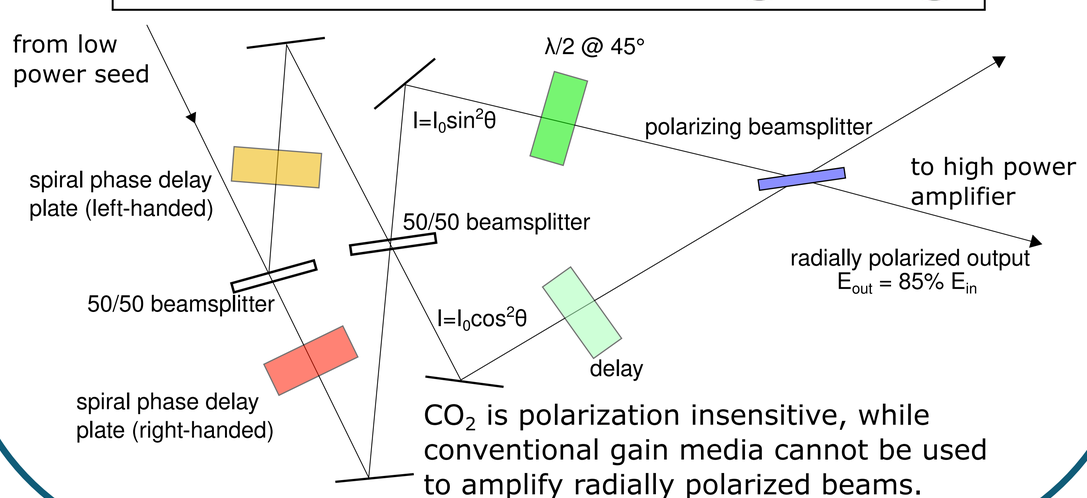
Strong longitudinal fields can be used to accelerate electrons in vacuum.
Radially polarized beams can confine the electron beam in the transverse direction with the radial electric field.
The combination of strong longitudinal field and transverse confinement leads to higher quality electron beams.





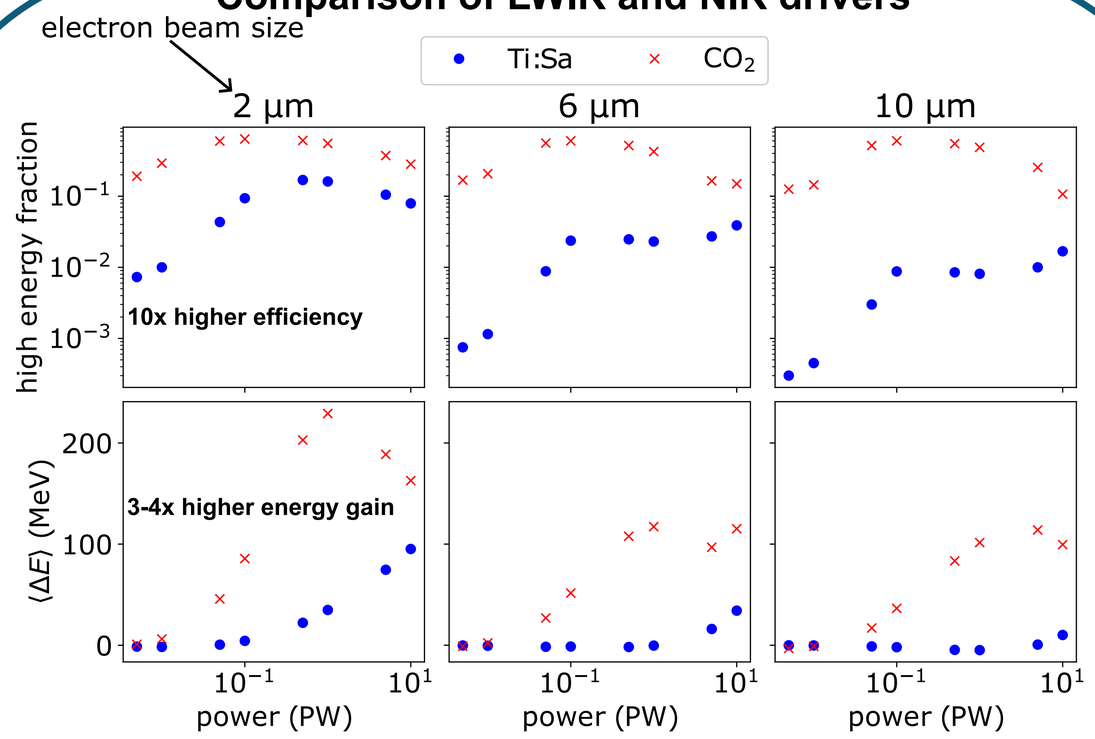
Generating radially polarized LWIR beams

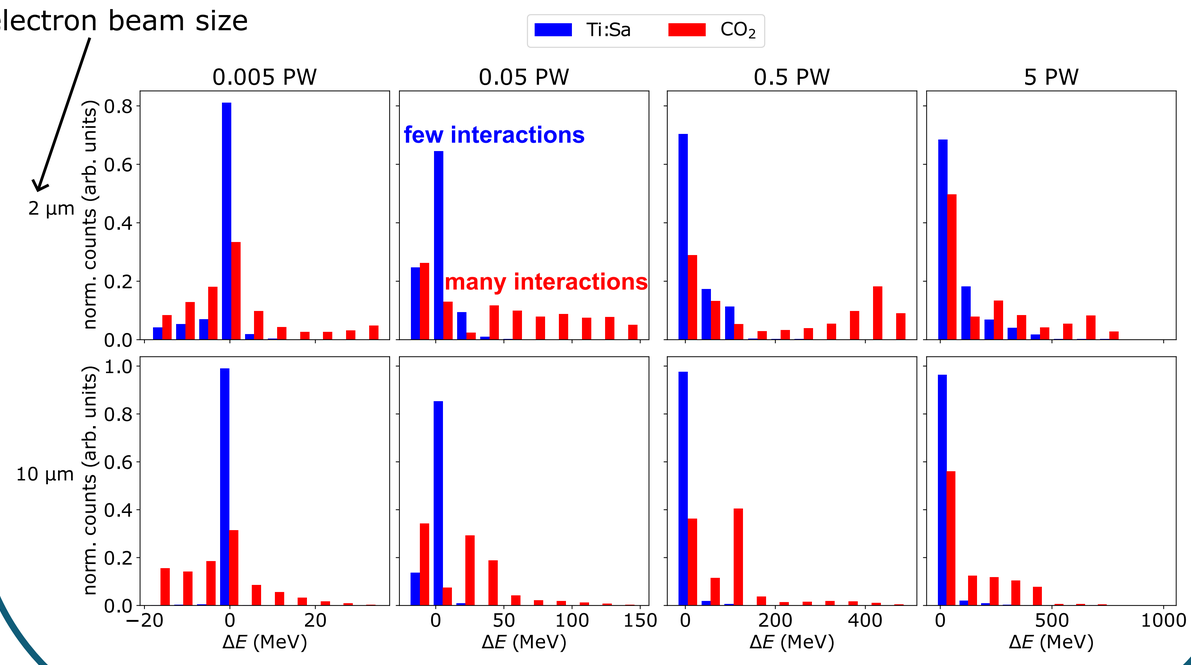




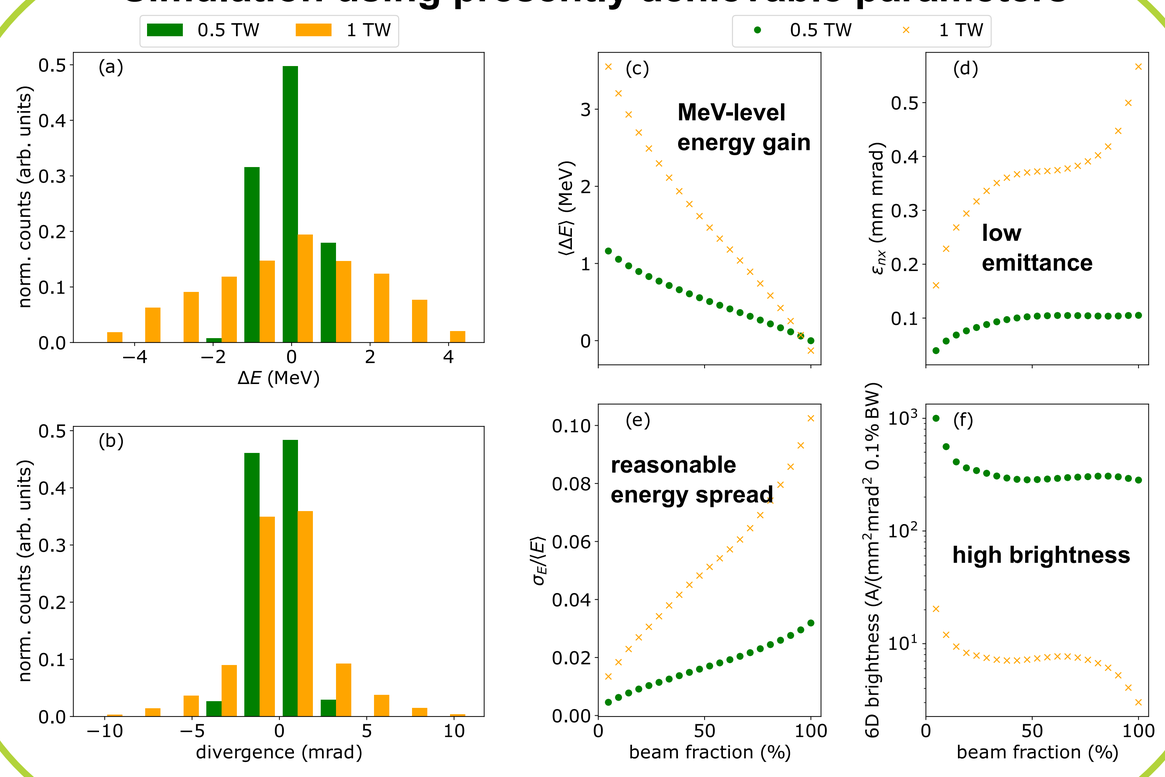
CO_2 is polarization insensitive, while conventional gain media cannot be used to amplify radially polarized beams.
Enables potentially higher peak powers.

Comparison of LWIR and NIR drivers[3]





Simulation using presently achievable parameters[3]



Conclusions

- Radially polarized beams are ideal drivers for direct laser acceleration
- Longer wavelengths enable superior acceleration efficiency and quality
- Polarization insensitivity of CO_2 could allow for higher peak powers
- MeV-level energy gain possible with presently available CO_2 laser

References

[1] Q. Zhan, *Adv. Opt. Photon.* **1**, 1-57 (2009)
[2] H. Tomizawa, H. Dewa, A. Mizuno, T. Taniuchi, *Proc. of LINAC 2012*, THPB068
[3] W. H. Li, I. V. Pogorelsky, M. A. Palmer, *Photonics* **11**, 1066 (2024)

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