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Generating and testing flying focus laser pulses with Lasy for PIConGPU simulations

— A Bachelors Defense —

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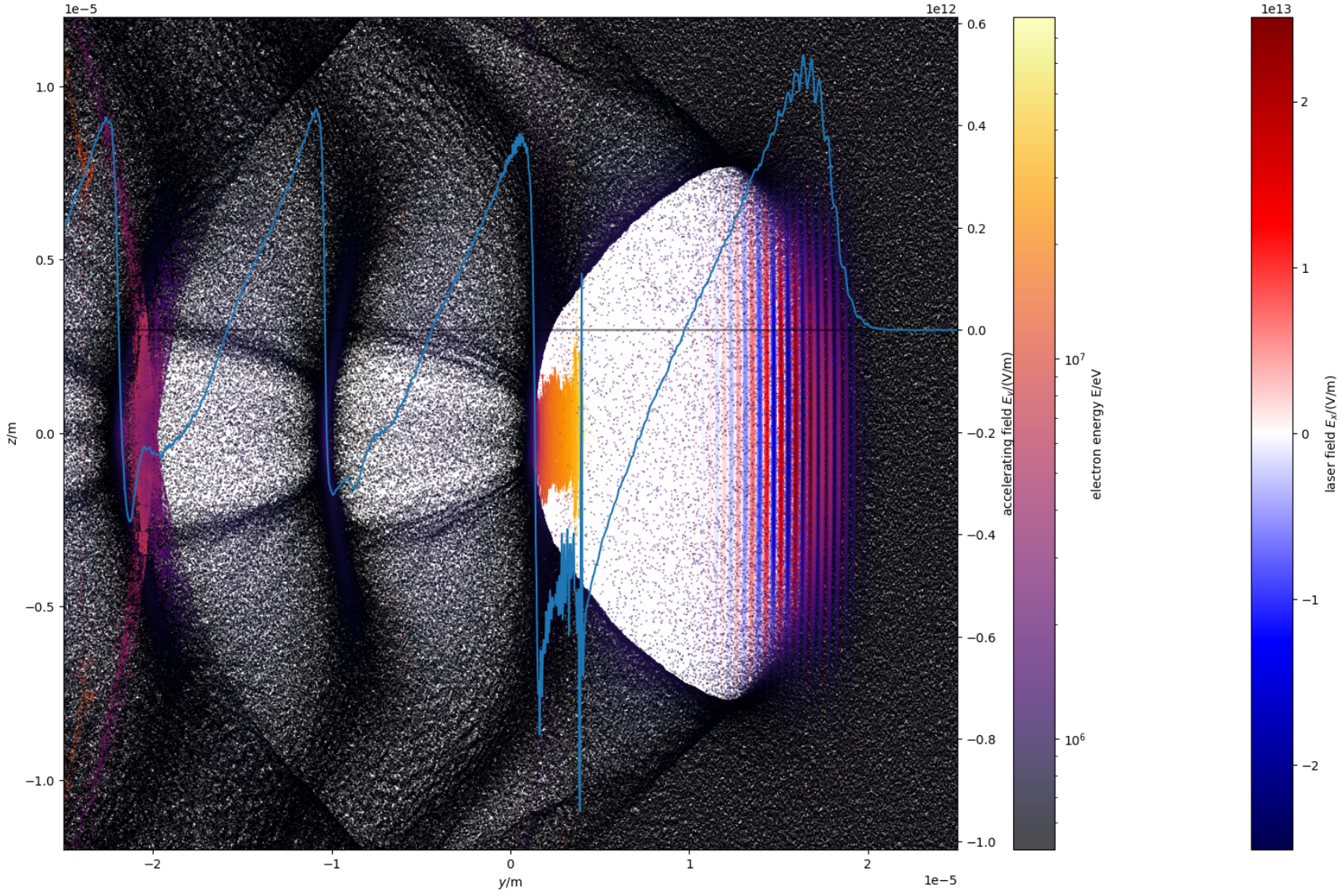
Laser WakeField Acceleration (LWFA) [1]



Electric field and electrons in an LWFA simulation.

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Flying focus lasers – solving the Problem of Dephasing

1. TWEAC [3]

- Traveling-Wave Electron ACcelerator
- Uses two laser pulses with tilted pulse fronts
- The tilt controls the velocity of the overlapping region

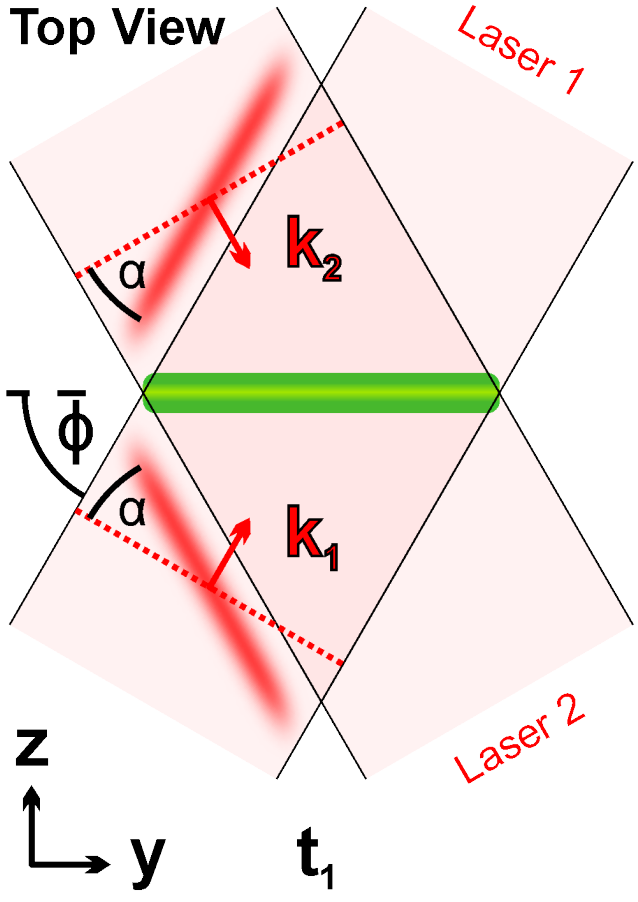

Image: TWEAC setup using two laser pulses. Image taken from Debus [2]

Flying focus lasers – solving the Problem of Dephasing

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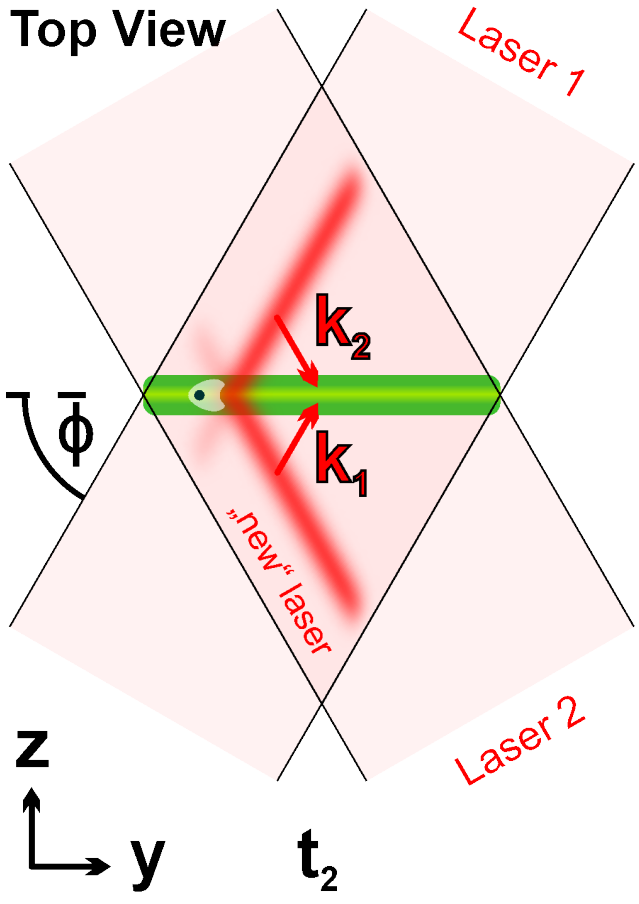

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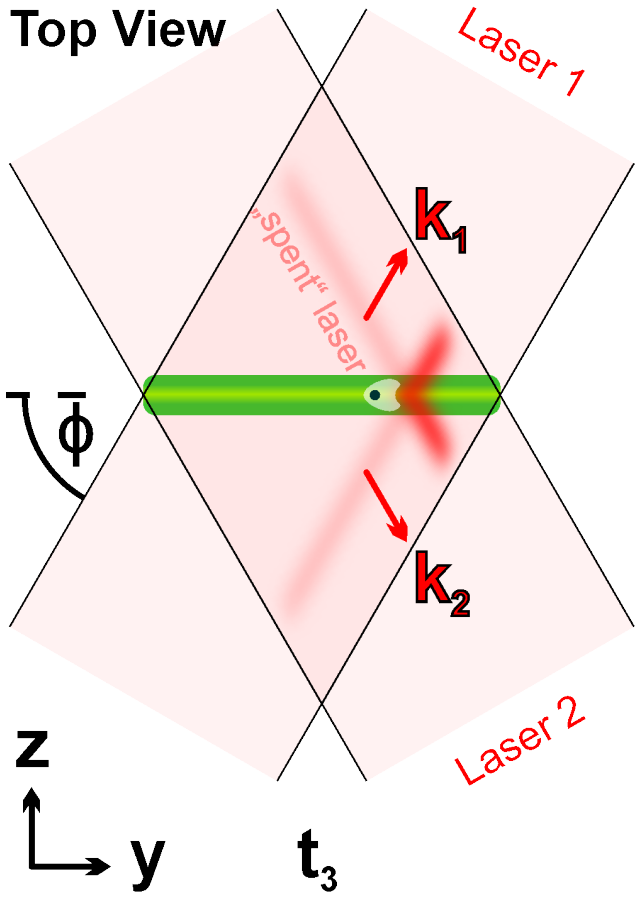

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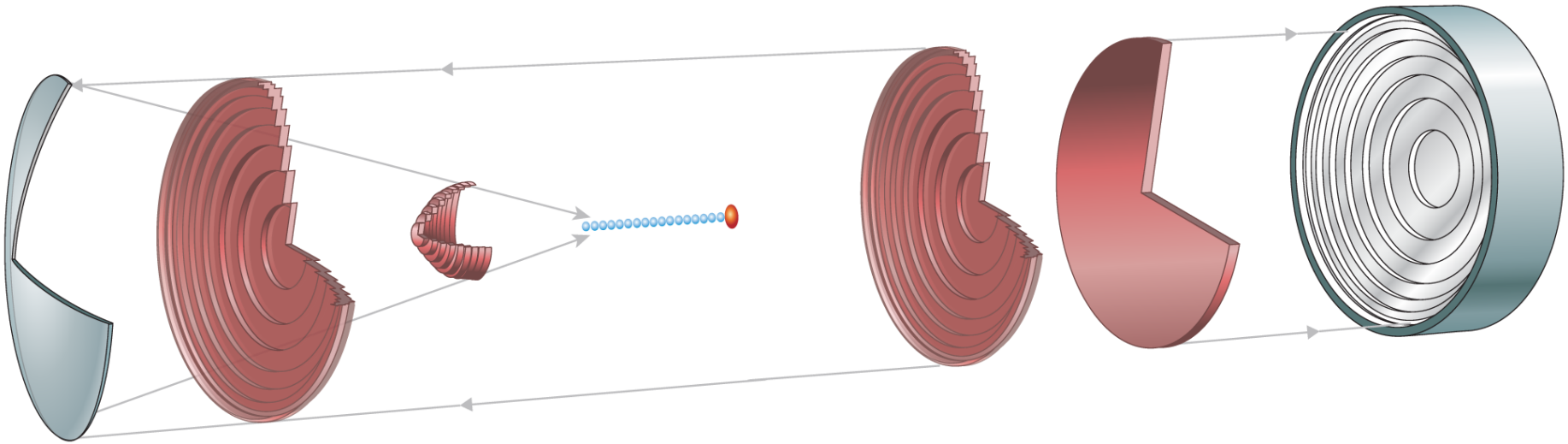
Flying focus lasers – solving the Problem of Dephasing

2. Axiparabola laser [4]

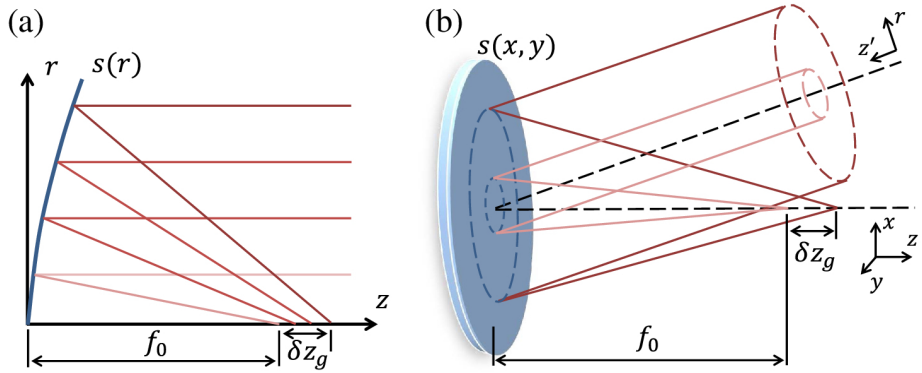


The flying focus setup. Two optical elements: The Axiparabola (left) and the Radial Group Delay echelon (RGD) (right). Image taken from Palastro et al [4].

Flying focus lasers – solving the Problem of Dephasing

2. Axiparabola laser [4]

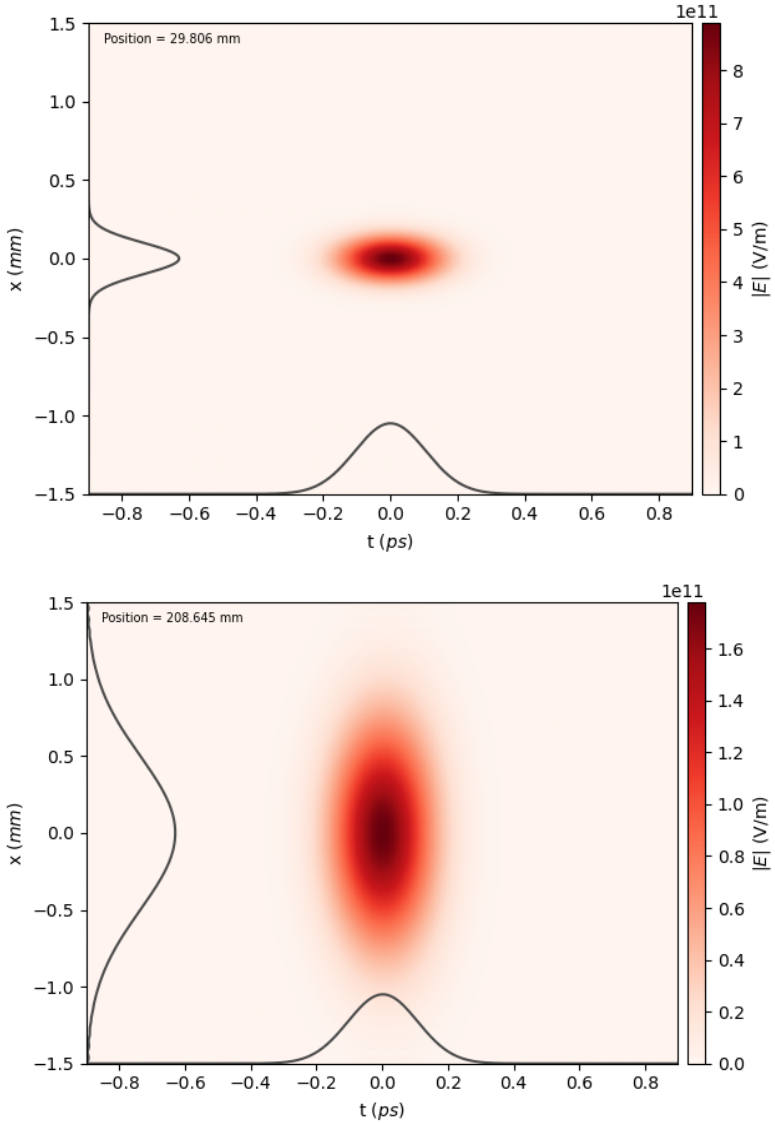
- Axiparabola [5]:
  - Near-parabolic mirror
  - Focuses light onto a line – the focus region
  - → Light at radius r is focused at $f(r) = f_0 + \delta \left(\frac{r}{R}\right)^2$
- Radial Group Delay echelon (RGD) [6][4]:
  - Stepped concentric mirror rings
  - Shape follows some function $\tau_D(r)$
  - → controls the timing of the axiparabola focus



Axiparabola functionality. Image taken from Smartsev et al [5].

Lasy [7]
A python library

- A python library for simulating Laser pulses in a vacuum
- Uses complex envelope of the laser field
- Uses angular spectrum propagation
- Can use cylindrical coordinates for memory and CPU time efficiency
- Offers a range of optical elements

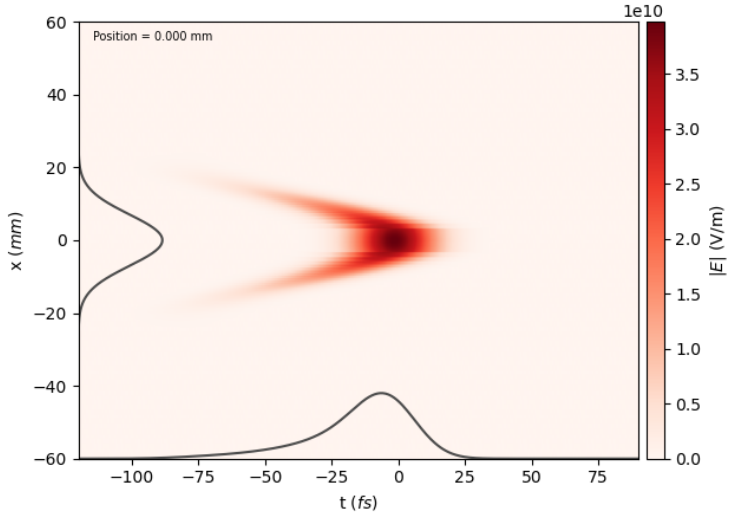


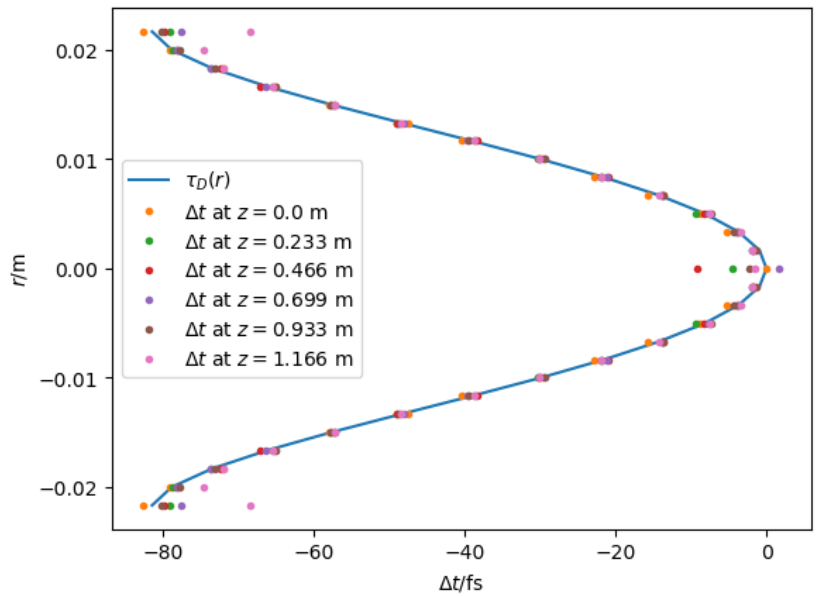
Images: Example of a Gaussian pulse being propagated by Lasy. Top: generated at the focus, Bottom: 6 z_R after the focus.

Implementing the flying focus

1. The Radial Group delay echelon (RGD)

- Implemented from scratch as Lasy optical element
- Following the description by Ambat et al [6]
- Shapes the pulse temporally without focusing or defocussing
- Can generate any radially symmetric shape $\tau_D(r)$





Images: A Gaussian pulse after interacting with the RGD. Top: field envelope, Bottom: Test results. even after long distances the shape still holds.

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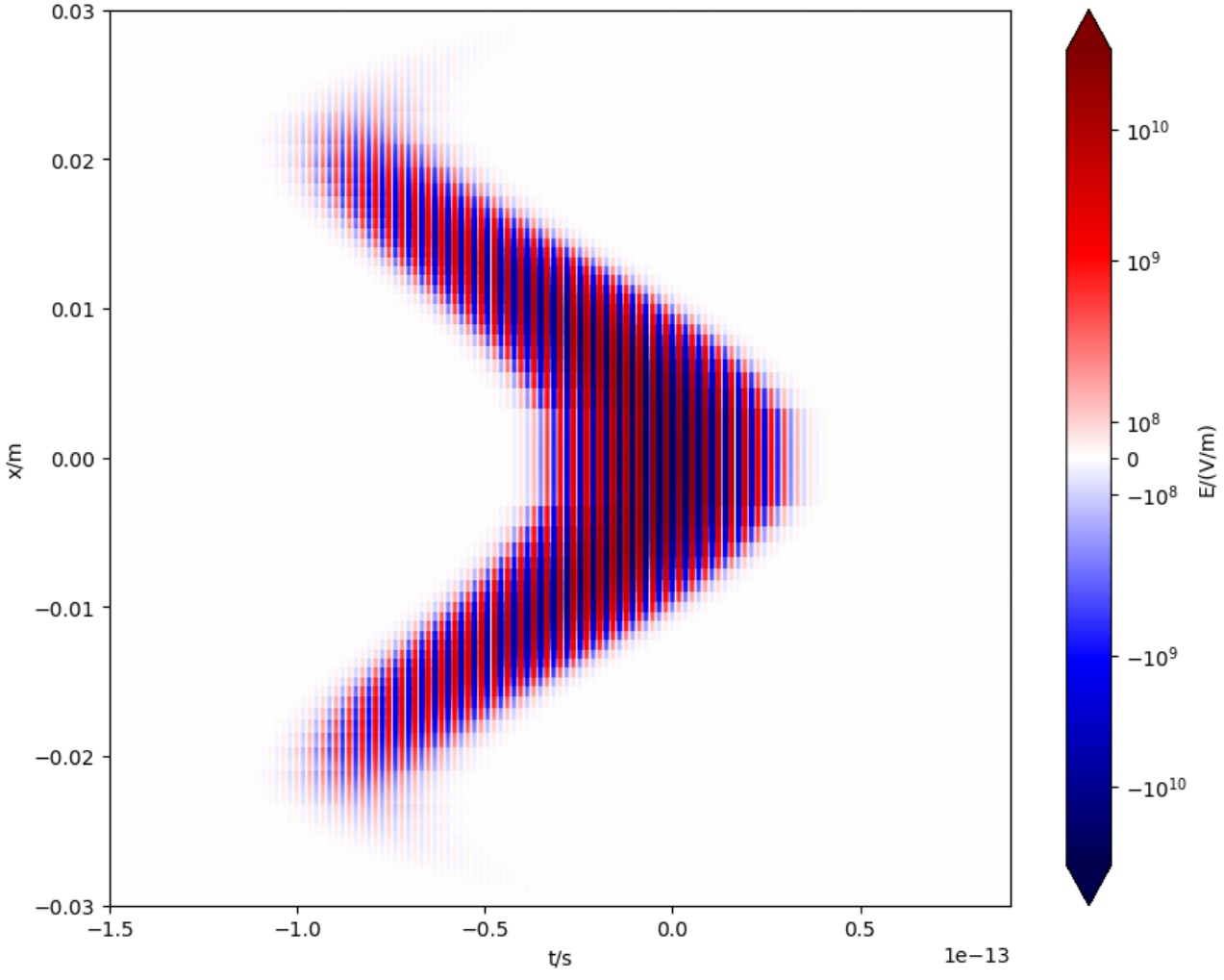
Implementing the flying focus

1. The Radial Group delay echelon (RGD)

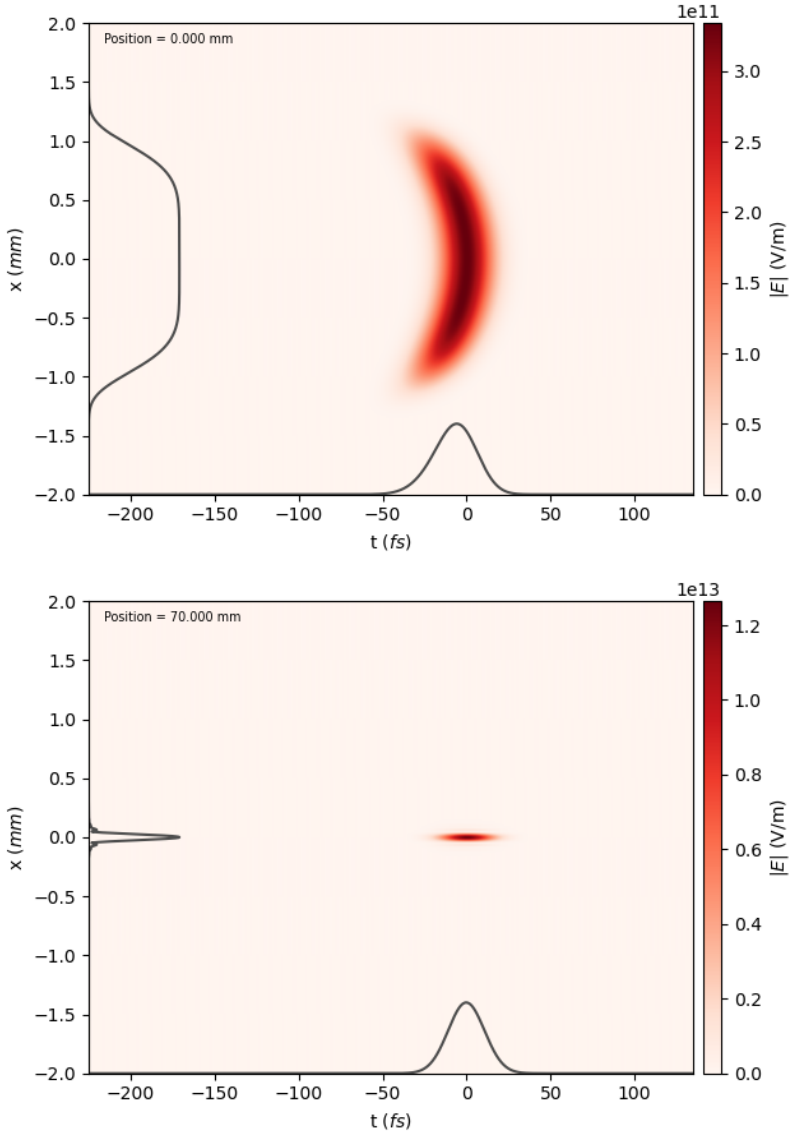


The electric field of the laser after interacting with the RGD.

Implementing the flying focus

2. The Axiparabola

- Included in Lasy
- Following Smartsev et al [5]
- ?



Images: A super-Gaussian laser pulse after reflecting off the axiparabola. Top: in the near field, Bottom: in the far field at the beginning of the focus region.

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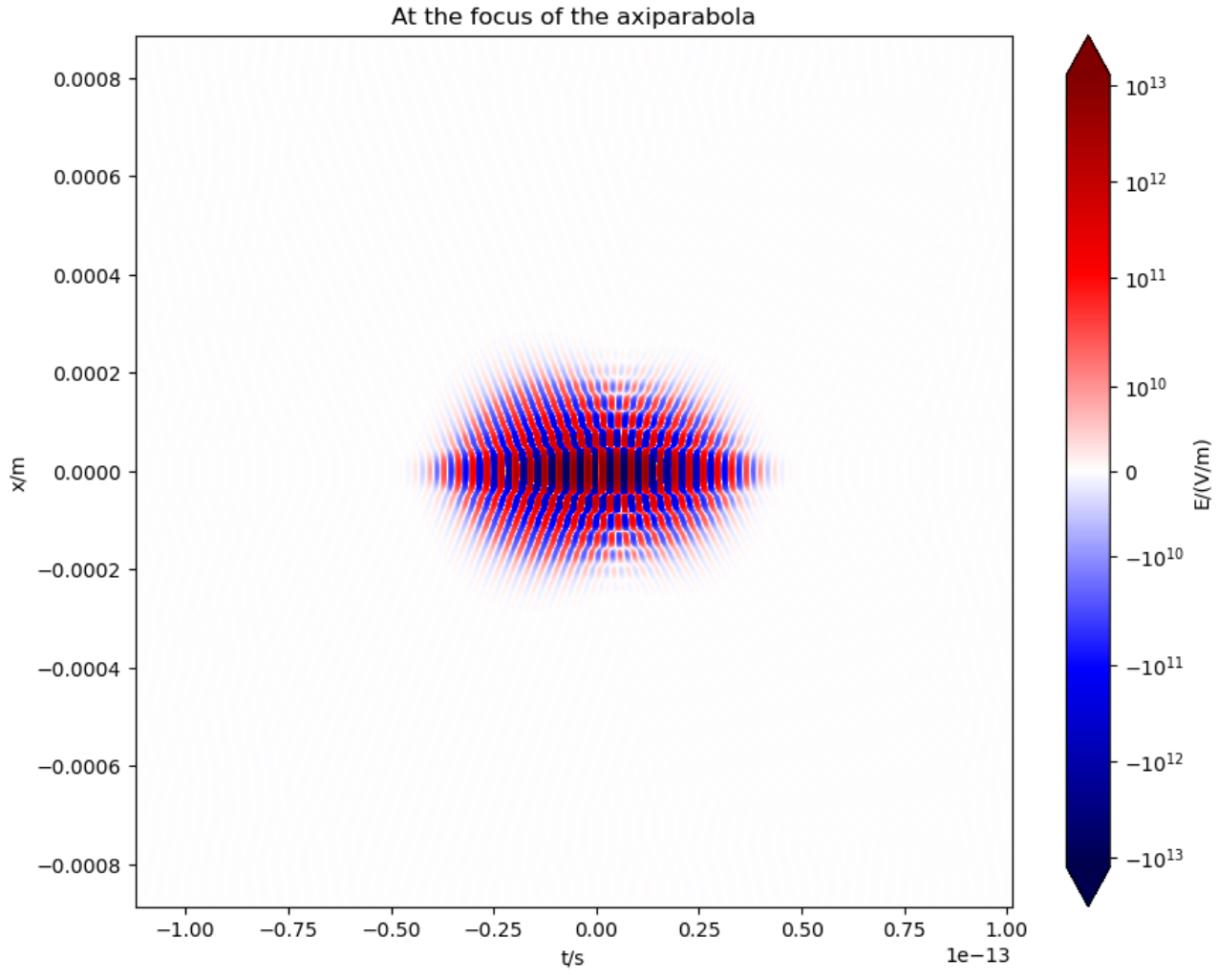
Implementing the flying focus

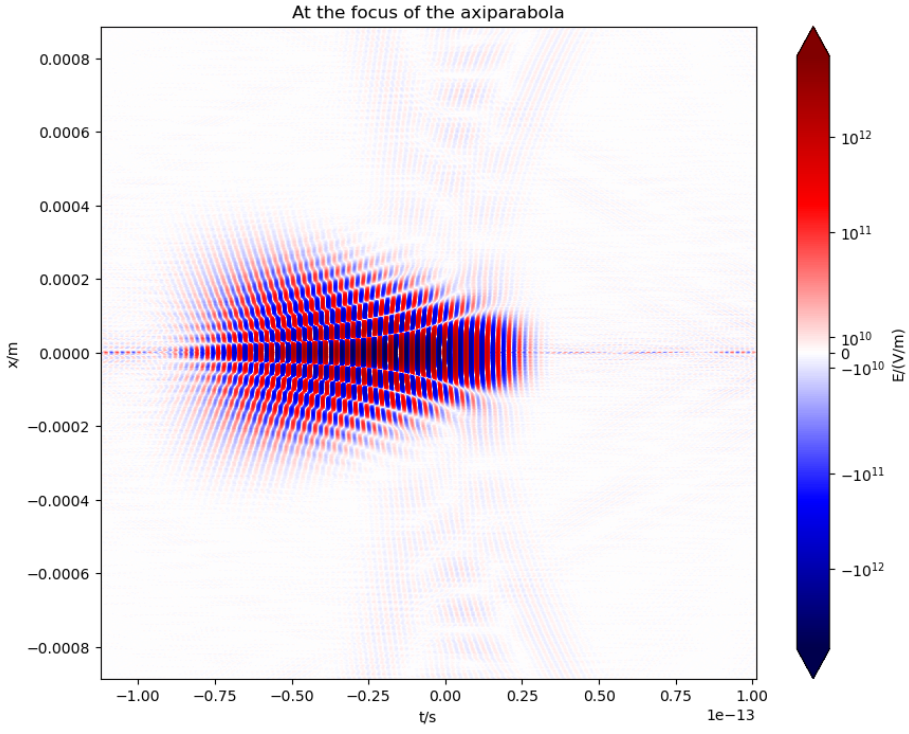
2. The Axiparabola



The electric field of the laser at the beginning of the focus region of the axiparabola.

Importing to PIConGPU

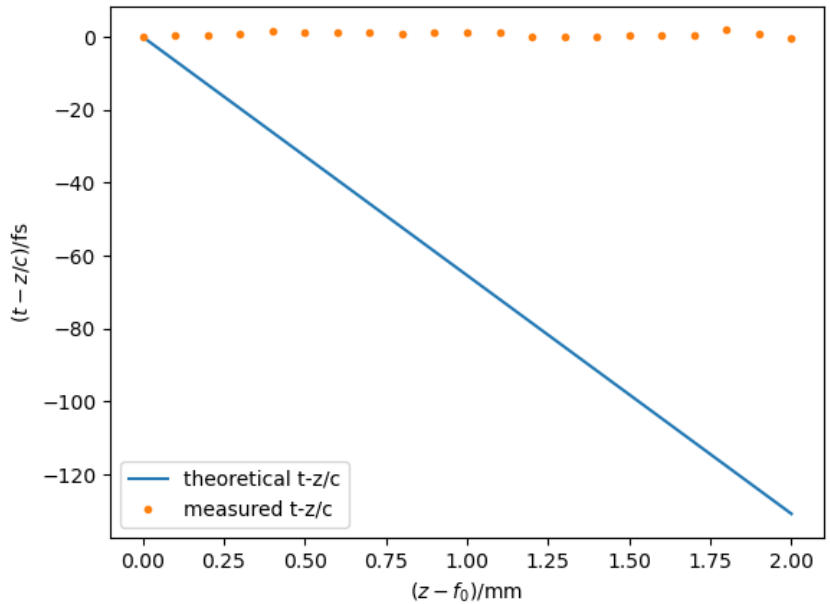
- New module `full_field`
- Generates full electric field and saves it using `openPMD-api`
-



Images: Electric field of the complete flying focus laser at the beginning of the focus region.

Testing the flying focus laser

First results



Testing the flying focus laser

Test

Conclusion

Remaining Possible reasons for failure

- The Axiparabola
- The Propagation
- The Findings in the other papers

Outlook

?

- Lasy lasers available in PIConGPU

→ ...

- LWFA with new laser setups possible

References (I)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Laser electron-accelerator.
Physical Review Letters, 43(4), 1979.


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