

Three dimensional bunch shaping for plasma wakefield accelerators.



G. Loisch, Y. Chen, J. Good, M. Gross, C. Koschitzki, M. Krasilnikov, O. Lishilin, A. Oppelt, F. Stephan

DESY Zeuthen, Platanenallee 6, 15738 Zeuthen, Germany

Abstract

Beam driven wakefield acceleration in plasmas is one of the most promising candidates for novel, compact accelerators. Several aspects of this acceleration scheme can be optimised by transverse and longitudinal shaping of the bunch that drives the wake and of the bunch that is accelerated in the wake.

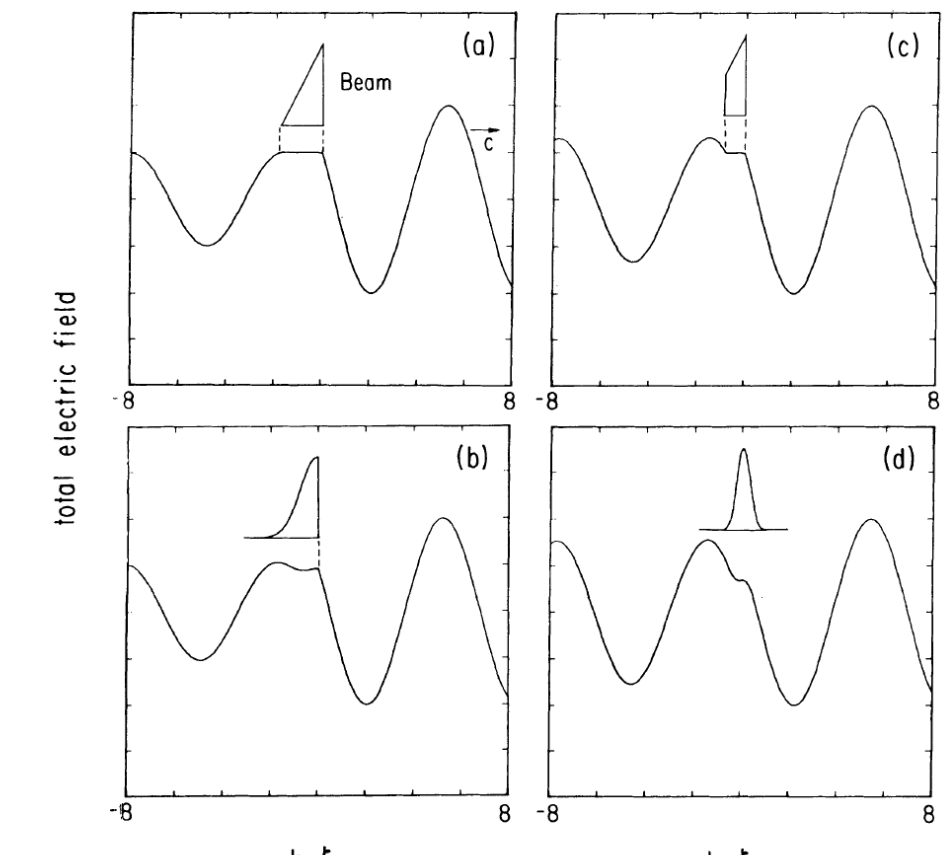
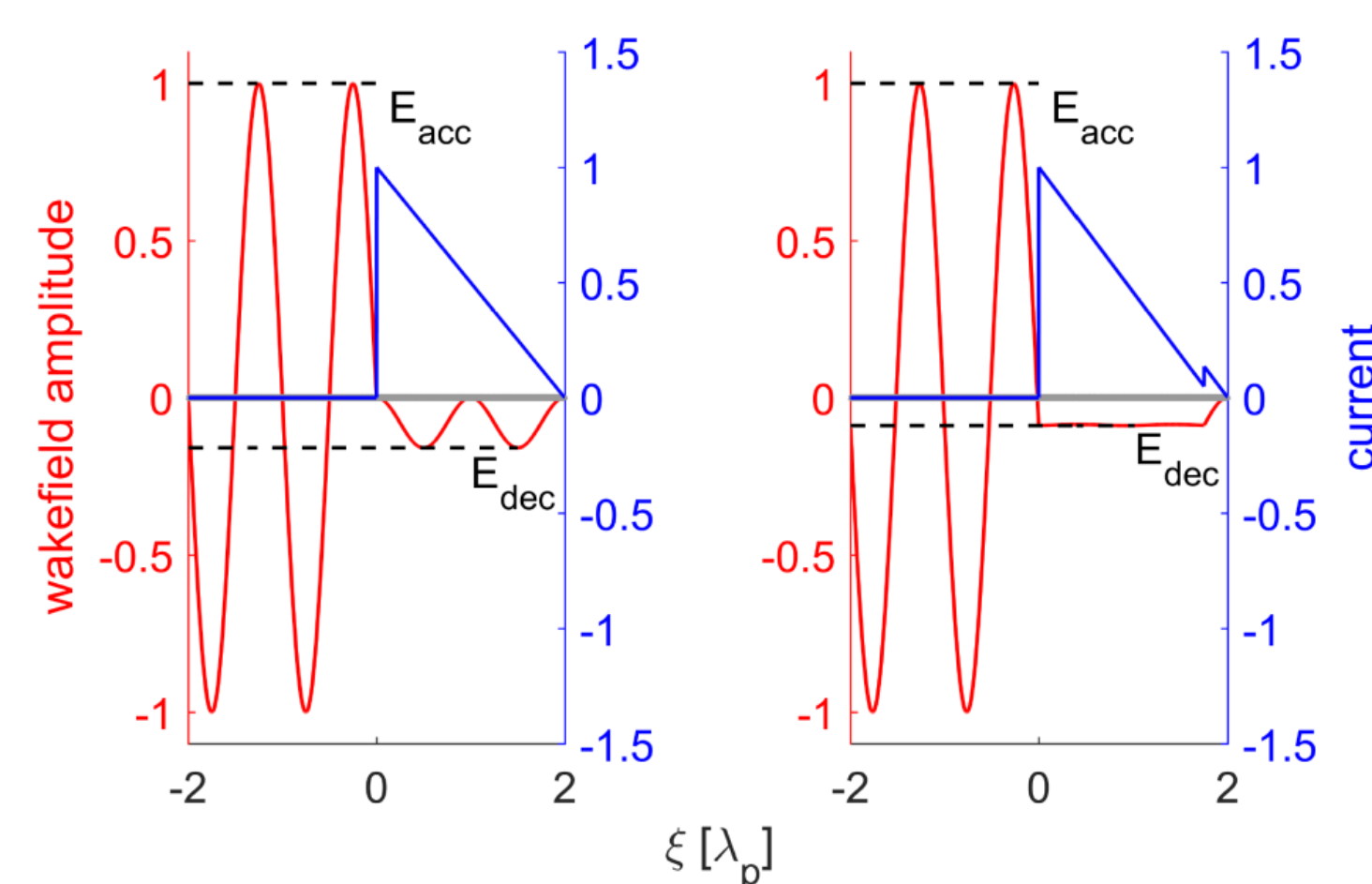
The ratio between acceleration of the witness and deceleration of the driver, the transformer ratio, can be increased when triangular driver bunch shapes are utilised.

By shaping the witness bunch longitudinal profile, the beam loading of the wake can be tuned, which allows reduction of the energy spread of the accelerated beam.

The necessary bunch shaping can be achieved by shaping of the photocathode laser pulses of a photoinjector. Here, we present simulations and first results of transverse and longitudinal bunch shaping with the new photocathode laser system at PITZ, with a pulse shaping section based on spectral masking using spatial light modulators.

Motivation

Providing 3D-shaped electron bunches for wakefield accelerators



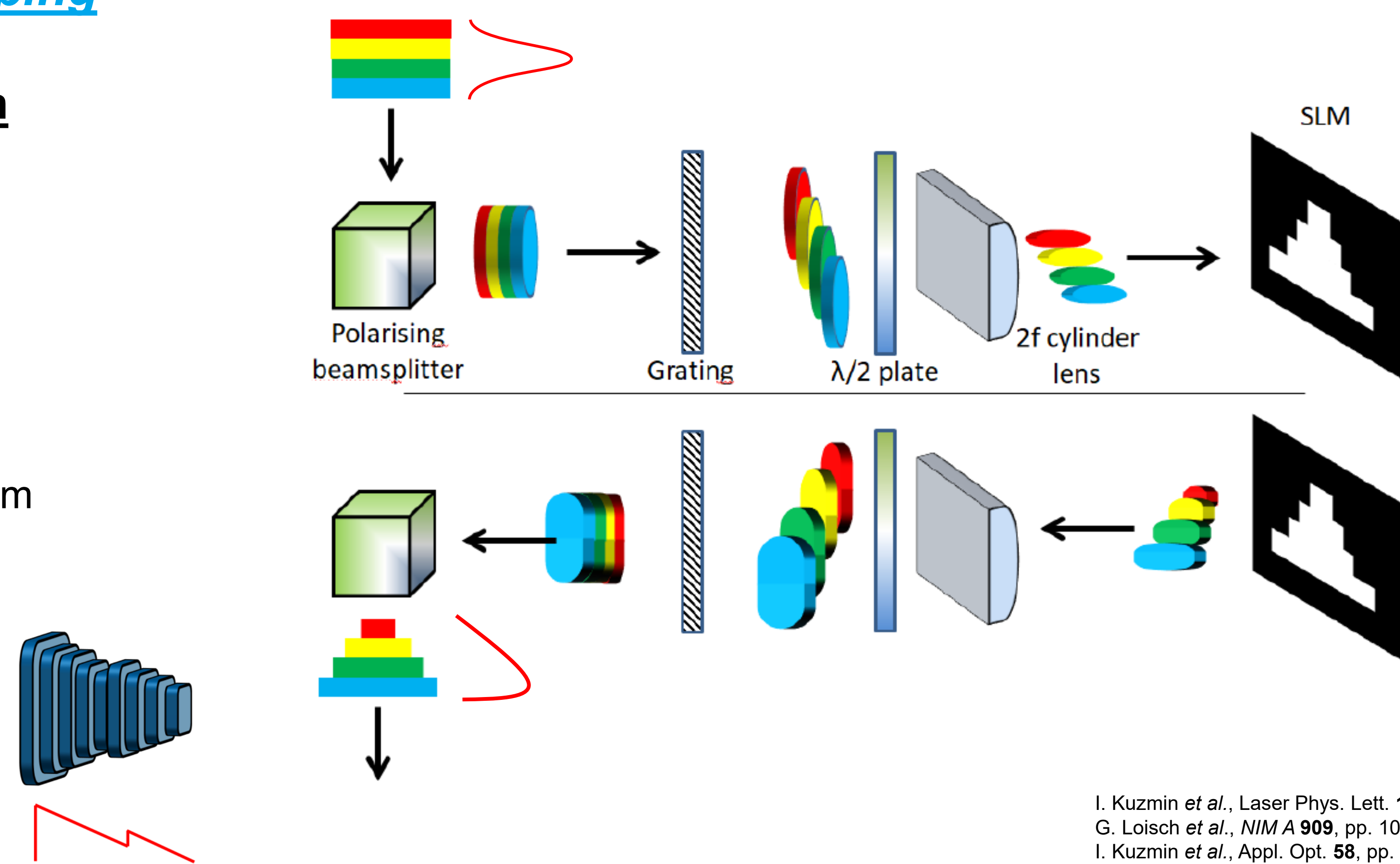
- ▶ Increase Transformer Ratio
- ▶ Control beam loading w/ shaped witness bunches
- ▶ Emittance minimisation for witness bunches
- ▶ Phase space manipulation

K.L.F. Bane *et al.*, IEEE Trans. Nucl. Sci., **NS-32** No. 5, pp. 3524-3526 (1985)
T. Katsouleas *et al.*, Part. Accel. **22**, pp. 81-99 (1987)

3D Photocathode-laser based bunch shaping

Spectral masking of chirped laser pulses with Spatial Light Modulators

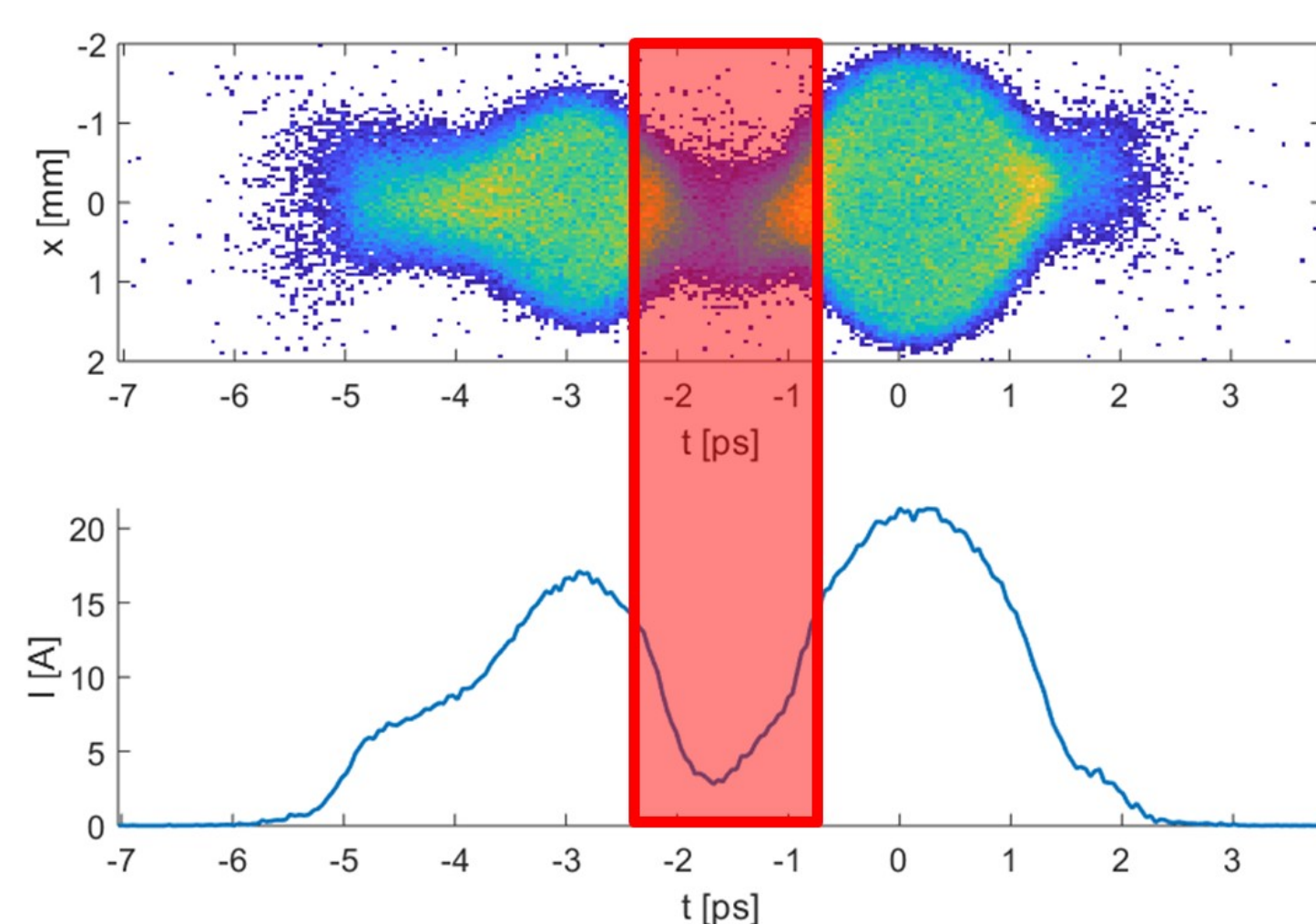
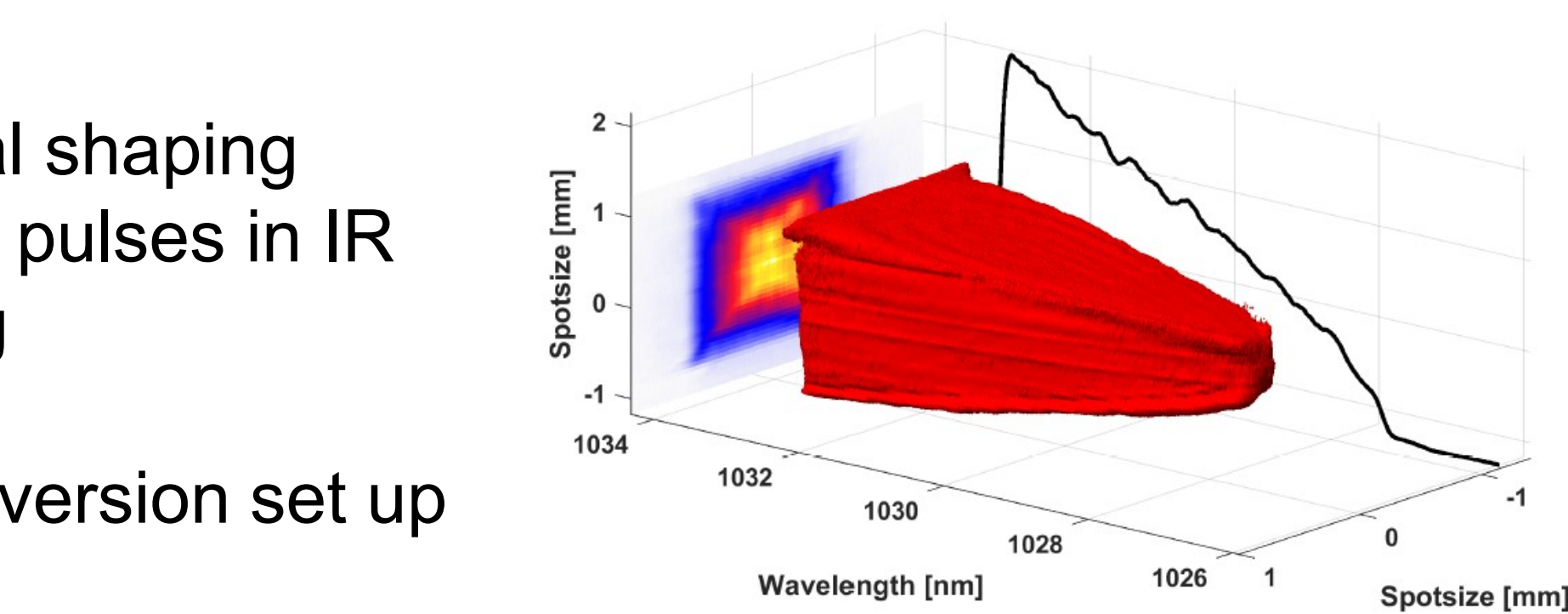
- ▶ 2D+2D shaping of laser pulses in $x-\lambda$ & $y-\lambda$ spectral domain (IR)
- ▶ Fourth harmonics conversion to UV
- ▶ Extraction of electron bunches with similar profile from photocathode
- ▶ “Direct” shaping
- ▶ No extra beamline equipment required
- ▶ No charge cutting in beamline



I. Kuzmin *et al.*, Laser Phys. Lett. **16**, 015001 (2018)
G. Loisch *et al.*, NIM A **909**, pp. 107-110 (2018)
I. Kuzmin *et al.*, Appl. Opt. **58**, pp. 2678-2686 (2019)

First experimental results

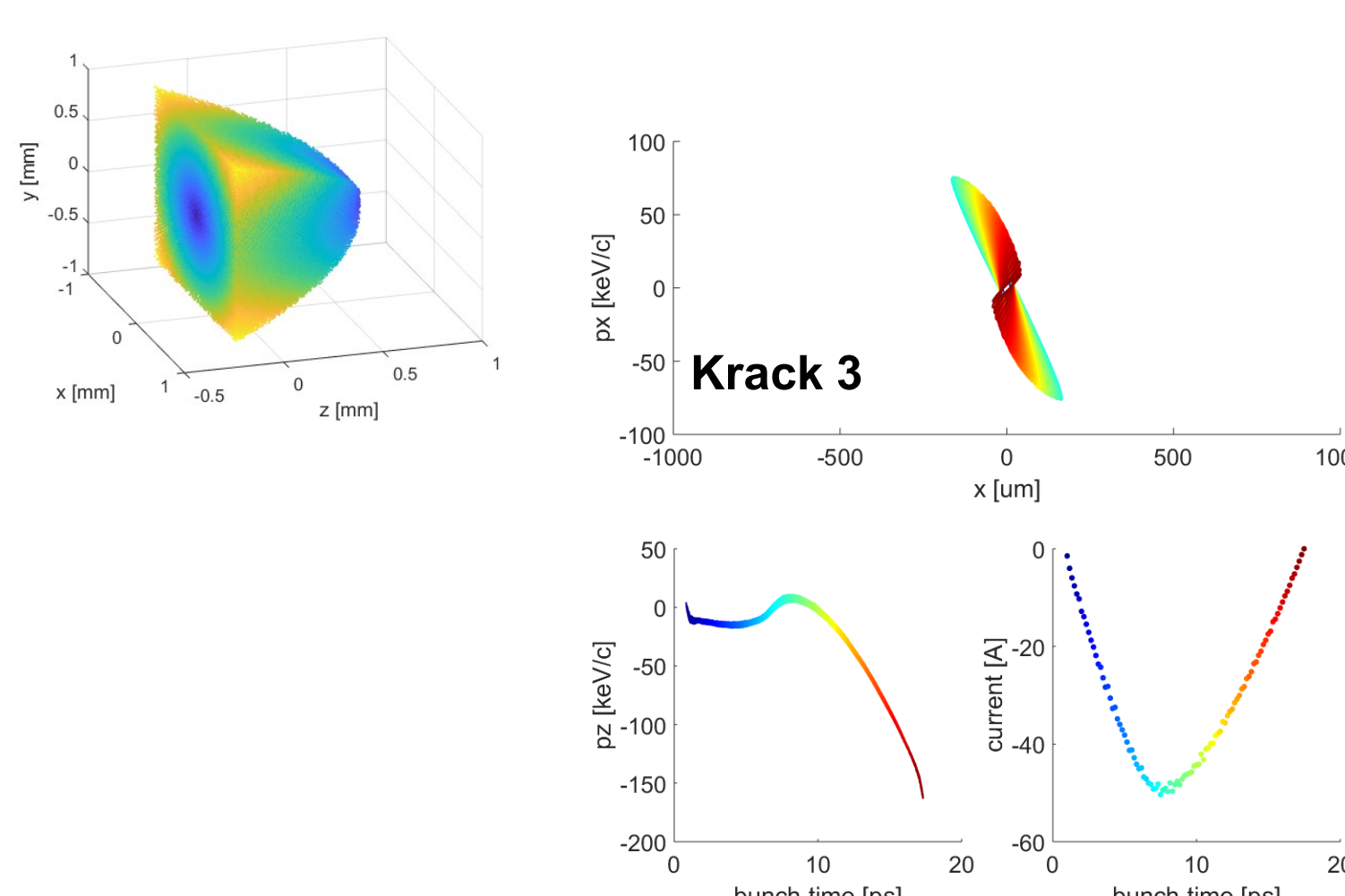
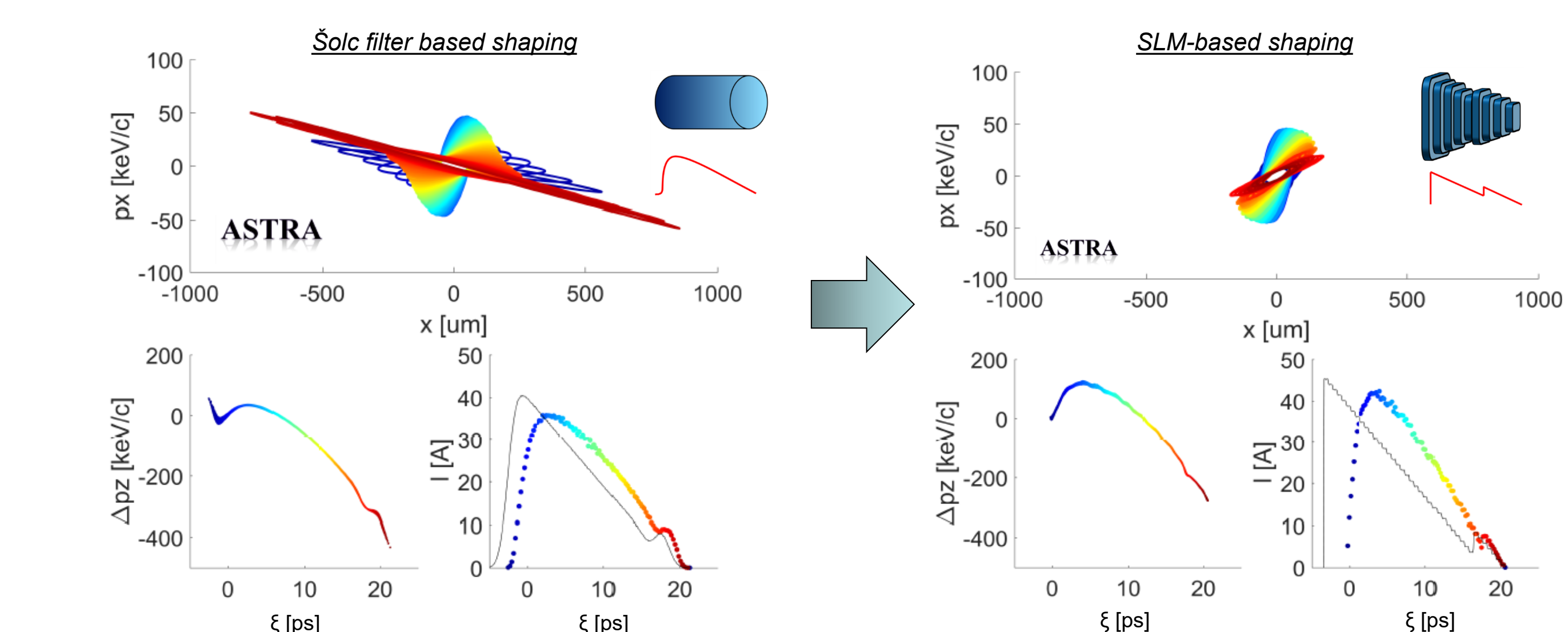
- ▶ Spectral shaping of laser pulses in IR working
- ▶ UV conversion set up
- ▶ Laser synchronised to PITZ RF with (50-100) fs timing jitter
- ▶ First “modified” electron bunches produced



Longitudinal profile of bunch with photocathode laser spectrum partially masked by SLM

Preliminary simulation results

- ▶ Strong slice mismatch reduction to current PITZ laser shaping method observed for rot. symmetric bunches (simulated w/ ASTRA)
- ▶ Preliminary full 3D tracking simulations (Krack 3.04) promising



Outlook

- ▶ Laser system still under commissioning
- ▶ Simulations ongoing
- ▶ First shaped UV pulses in coming months
 - ▶ Laser pulse and electron bunch characterisation