

# Software for laser plasma interactions: open-source workbench in Weizmann Institute of Science

Center for Intense Laser Science  
Department of Physics of Complex Systems



Weizmann Institute of Science



# NEW LABORATORY FOR LASER PLASMA SCIENCE

## Interests

- Laser-plasma acceleration of electrons and protons
- Secondary X-ray sources
- Near/under-critical gas targetry development
- Application studies

## Theory & Simulations

- Hydrodynamics
- Particle-In-Cell
- SR/FEL radiation

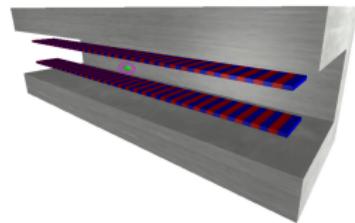
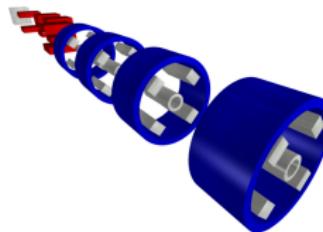
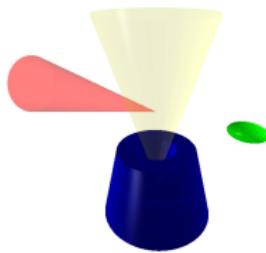
## Experiment

- Laser: 25 fs,  $2 \times 100$  TW
- Targetry: gas nozzle/cell, discharge, solid foils
- Particles and radiation sources and diagnostics

## Members

- 4 PhD students: D. Levy, E. Levine, O. Seeman, S. Smartsev
- 2 Staff scientists: I. Andriyash, E. Kroupp
- 1 Post Doc: Y. Wan
- 2 Technical staff: M. Adelberg (laser engineer), R. Piliposian (technician)
- 1 P.I.: Victor Malka

# NUMERICAL TOOLS REQUIREMENT



## Plasmas

### CFD codes

- compressible sonic solver
- viscosity, turbulence etc

### PIC codes

- 3D/quasi3D
- Full relativistic kinetics
- Elementary processes

### QSA codes

- Laser
- Coupling with PIC

## Beam Transport & Diags

### Pusher trackers

- Space-charge
- CSR

### Matrix trackers

- Large e-spectra
- Beamline tuning

### Magnetostatic codes

- Equipment modeling

## Secondary Light Emission

### SR light

- Real orbits integral
- Field propagation

### FEL amplification

- 3D/quasi3D
- Time-dependent
- Non-averaged

# OPEN-SOURCE SOLUTIONS

## PIC codes

- FBPIC<sup>q3D, PSATD, GPU</sup>
- WARP<sup>+q3D, PSATD</sup>
- EPOCH (+ PSC)
- PIConGPU<sup>+GPU</sup>
- ChimeraCL<sup>q3D, PSATD, GPU</sup>
- Architect<sup>RZ, Fluid</sup>
- QuickPIC<sup>QSA</sup>
- Piccante/ALaDyn<sup>+XPL</sup>
- VPIC
- Smilei
- iPic3D

## Transport

- ELEGANT<sup>ALL</sup>
- ASTRA<sup>RK,SC,SCR</sup>
- OCELOT<sup>MTRX,SC,SCR</sup>
- AT<sup>MTRX</sup>
- Beta<sup>MTRX</sup>
- WARP<sup>PIC</sup>
- Synergia<sup>PIC</sup>

## Hydrodynamics

- OpenFOAM
- COOLFluiD

## SR

- SRW<sup>SR,Prop</sup>
- XRT<sup>SR,Prop,GPU</sup>
- CHIMERA<sup>SR</sup>
- Shadow3 (OASYS)\*
- OPC<sup>Prop</sup>

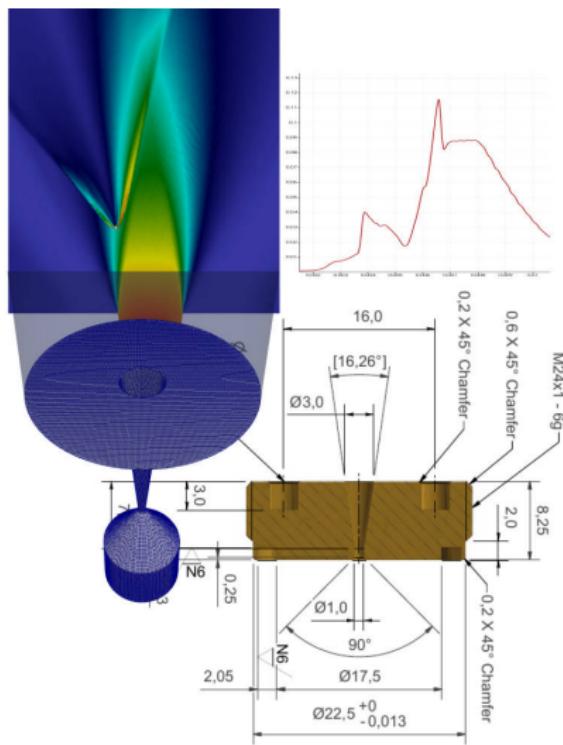
## FEL

- GENESIS<sup>3D,TD</sup>
- PUFFIN<sup>3D,TD, unav</sup>
- CHIMERA<sup>3D,TD</sup>
- FEL Booklet (PARSIFEL)

# DESIGNING THE LASER PLASMA ACCELERATOR

## Gas targetry

- Nozzle design (STL model):
  - SALOME (via 
  - SolidWorks (via 
- 2D/3D Meshing
  - SALOME (via 
  - ANSYS Meshing (via 
  - SnappyHexMesh (via 
- CFD modeling
  - OpenFOAM 
  - ANSYS FLUENT 
- Post-processing
  - Paraview (via 

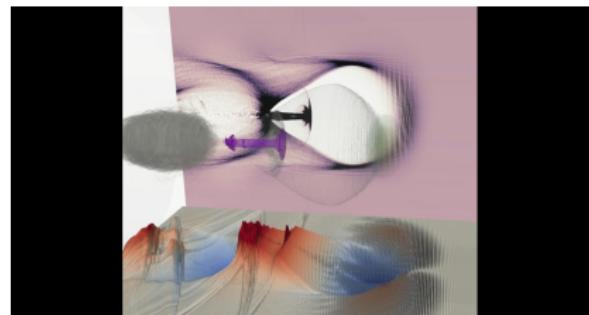


# DESIGNING THE LASER PLASMA ACCELERATOR

## Kinetics of laser plasma

### Particle-In-Cell:

- FBPIC (q3D, PSATD)
  - High accuracy, LBF, etc
  - Fast and convenient
- WARP (3D/q3D, FDTD)
  - Scalable and convenient
- CHIMERA(CL) (q3D, PSATD)
  - Toy for OpenCL learning
  - Fast, unstable



### Post-processing:

- OpenPMD\_viewer
- Paraview
- zillion of home-made scripts

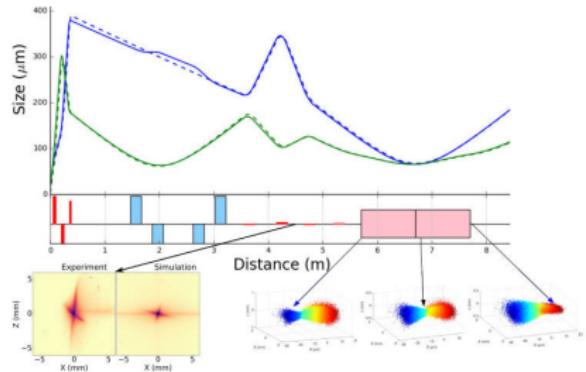
# DESIGNING BEAM APPLICATIONS

## Beam Transport

### OCELOT

(EuXFEL/DESY/Kurchatov Inst.):

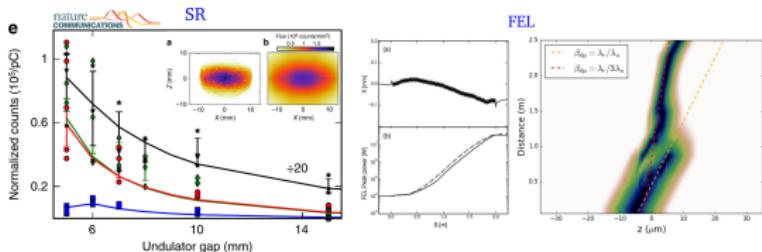
- optics
- tracking
- matching
- collective effects
- continuous spectra (ext)



## Radiation generation

### CHIMERA (FEL/SR/PIC)

- near- and far-field SR
- pusher external fields
- unaveraged FEL
- space-charge kicker



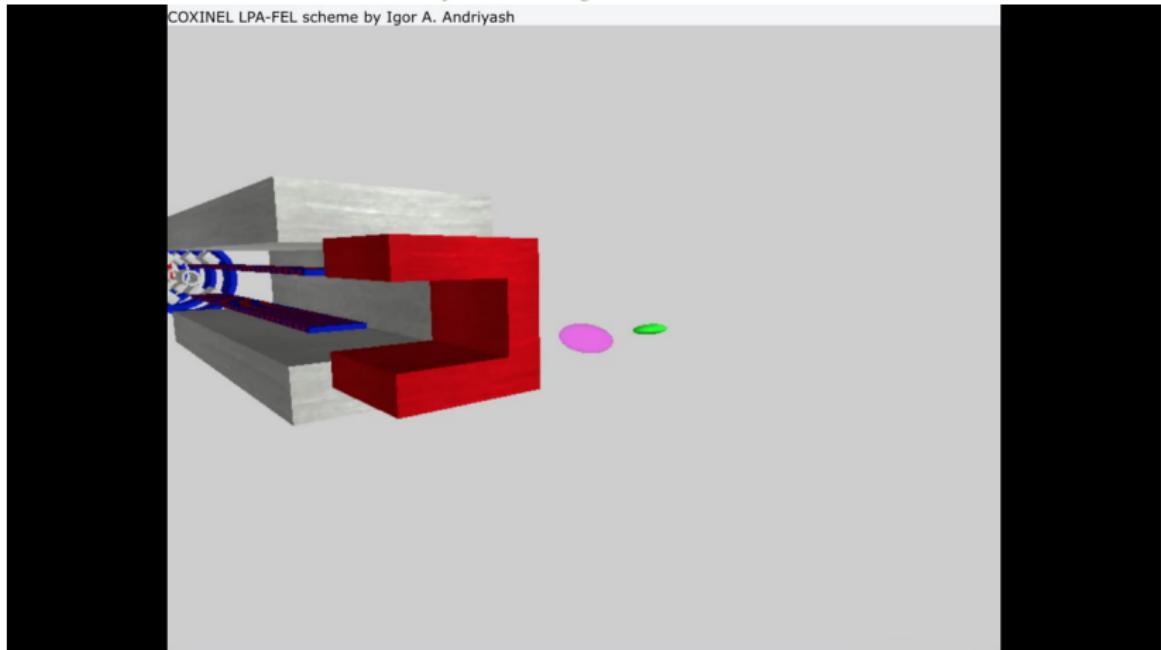
# LPA-DRIVEN SR/FEL SOURCE

COXINEL project



*T. André, I.A. Andriyash, A. Loulergue et al Nat. Comms 9:1334 (2018)*

COXINEL LPA-FEL scheme by Igor A. Andriyash

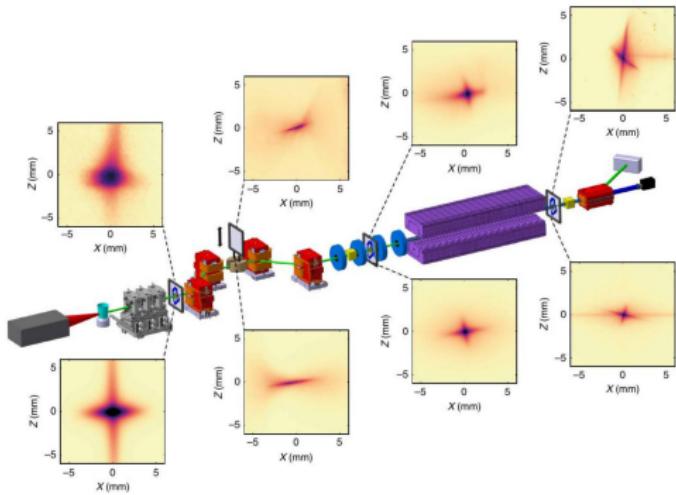


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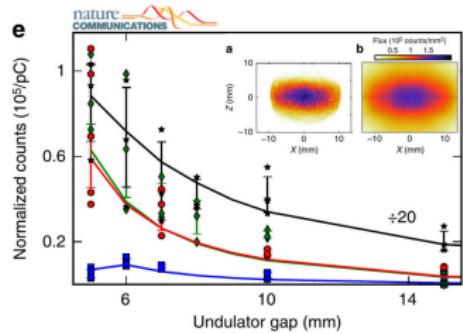
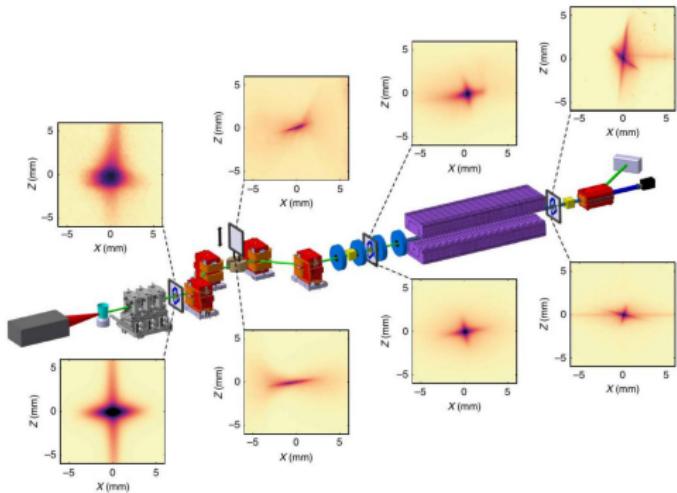


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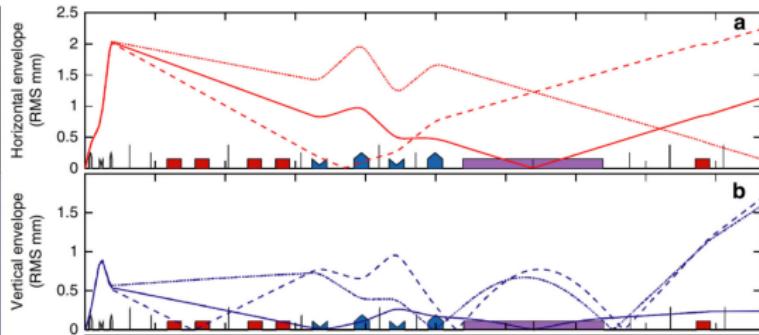
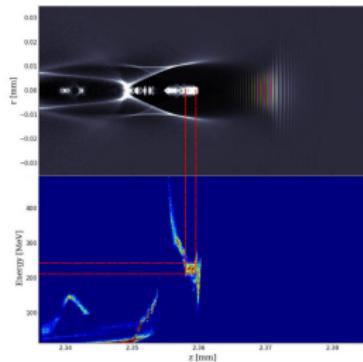


# LPA-DRIVEN SR/FEL SOURCE

COXINEL project



- PIC simulations of the LPA
- Beamline design and tuning with transport code

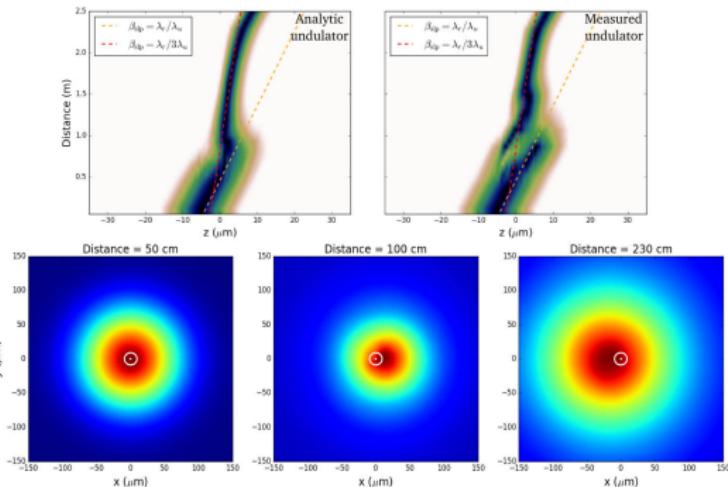
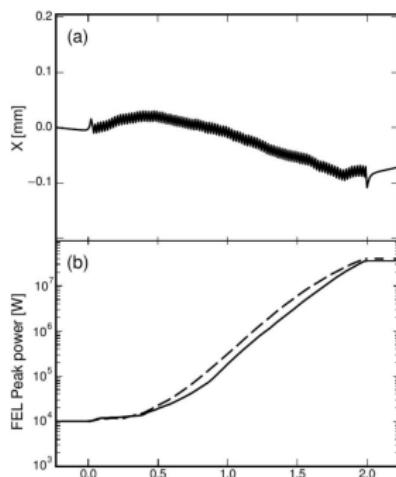


# LPA-DRIVEN SR/FEL SOURCE

COXINEL project



- FEL amplification study
- Measured undulator → orbits deviations



# SUMMARY

- Vast variety of available open-source numerical tools
- BLAST codes WARP and FBPIC: fast, scalable and user-friendly
- OpenPMD make analysis fast and easy