Universität Hamburg
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Exploring the physics of external electron-bunch injection into laser-driven plasma wakes at REGAE

Charlotte Palmer

K. Floettmann, J. Grebenyuk, J. Hirscht, T. Kleinwaechter, M. Kuhn, T. Mehrling, D. Miller, L. Schaper, M. Schnepp, J. -P. Schwinkendorf, B. Zeitler, F. Gruener and J. Osterhoff

Alexander von Humboldt Stiftung/Foundation

PHYSICS AT THE TERA SCALE Helmholtz Alliance

HELMHOLTZ ASSOCIATION

Accelerator Research and Development

Laser driven wakefield acceleration of electrons

- Self-injection
  - Narrow energy spread ~ GeV beams (Mangles et al. 2004, Geddes et al. 2004, Faure et al. 2004)
  - Unreliable beams - due to injection process or acceleration itself?
- Controlled injection
  - Down-ramp injection (Gonsalves et al. 2011), ionisation injection (Pak et al. 2010), colliding pulse injection (Lundh et al. 2011)
- External-injection
  - Continuous beams (Dewa et al. 1998, Dorchies et al. 1999)
  - `Short' electron bunches $\longrightarrow$ REGAE

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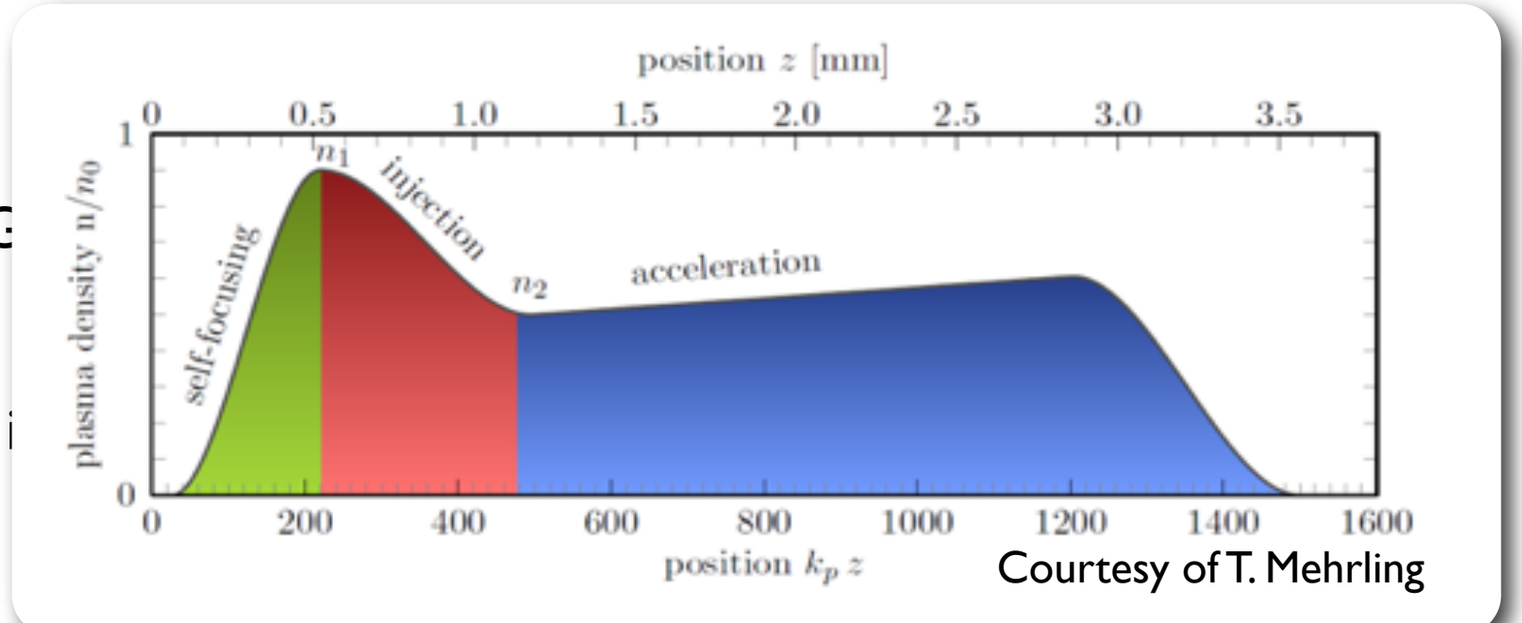
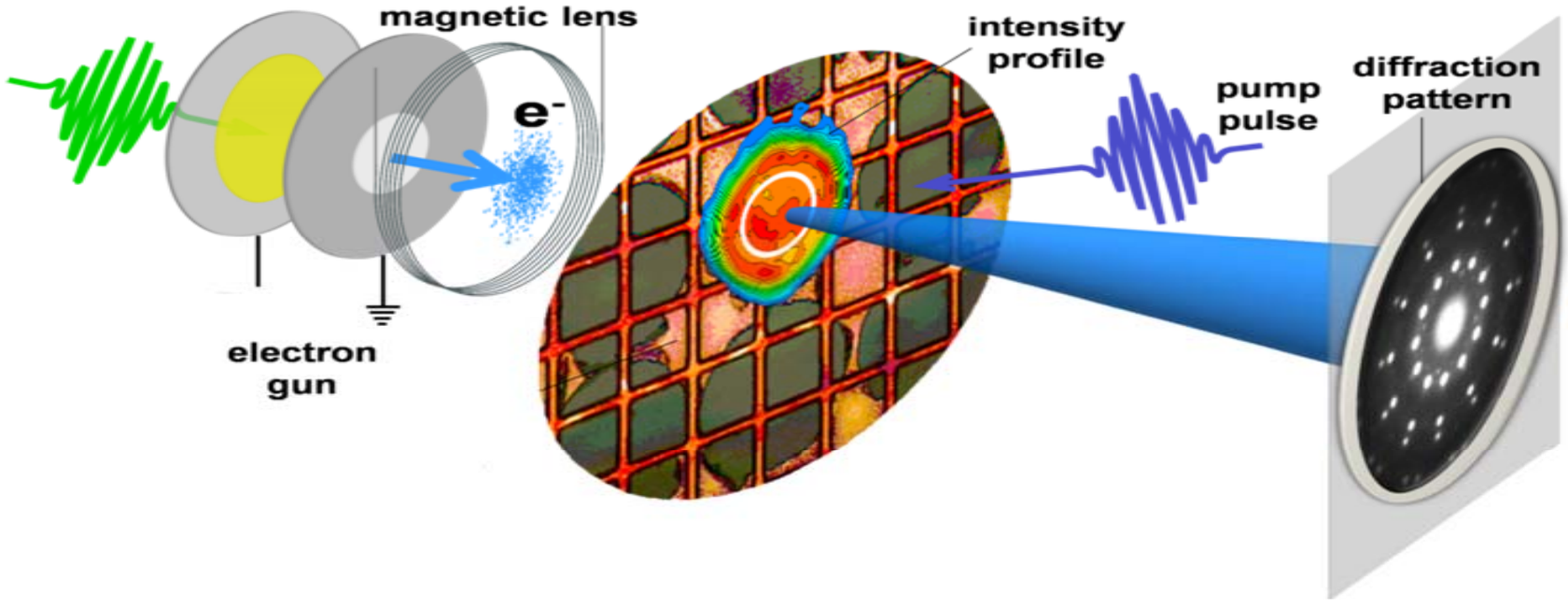


Courtesy of T. Mehrling

REGAE

- Relativistic Electron Gun for Atomic Exploration
  - Electron diffraction experiments - Prof. Dwayne Miller



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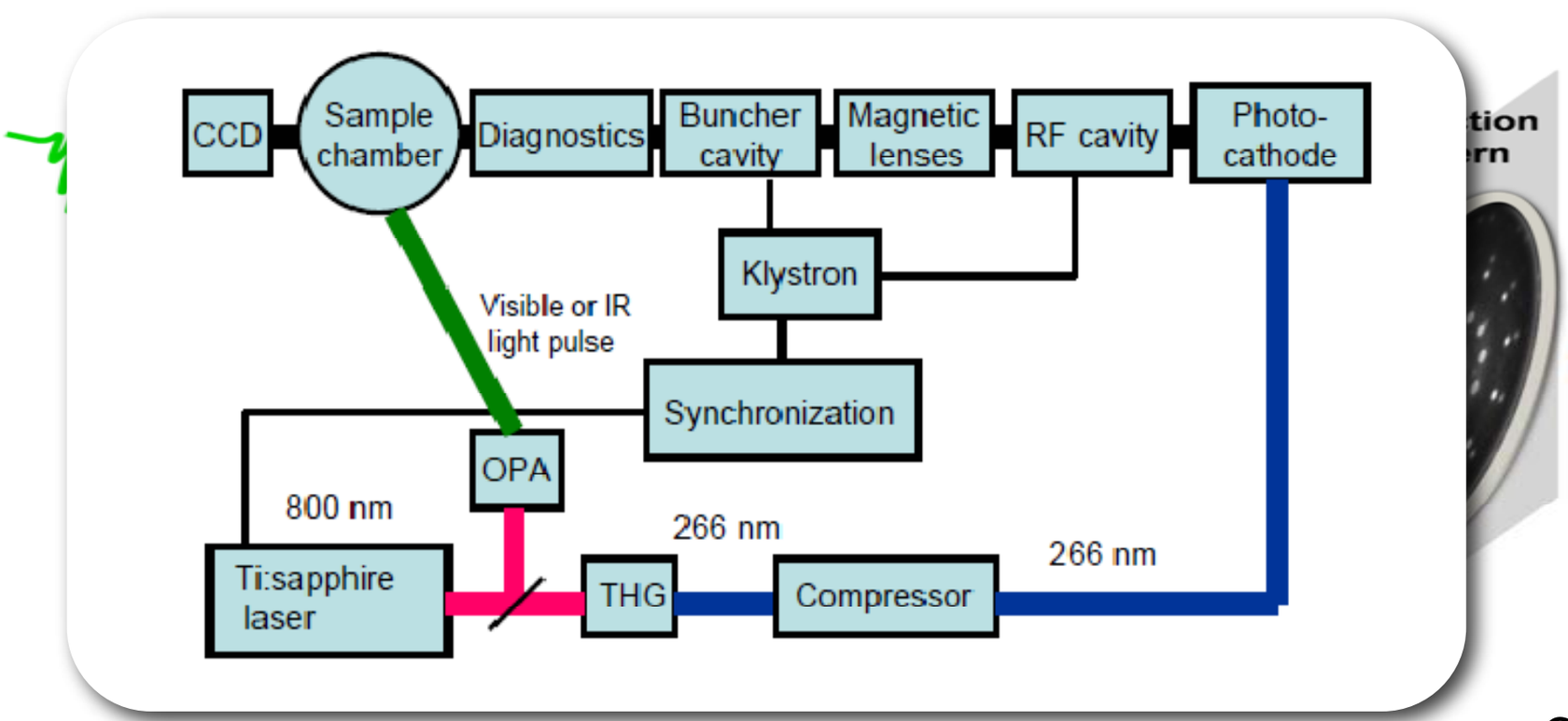
  - Compact electron gun:
    - photocathode, buncher cavity, ...



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Characteristics:

$E = 5$ MeV

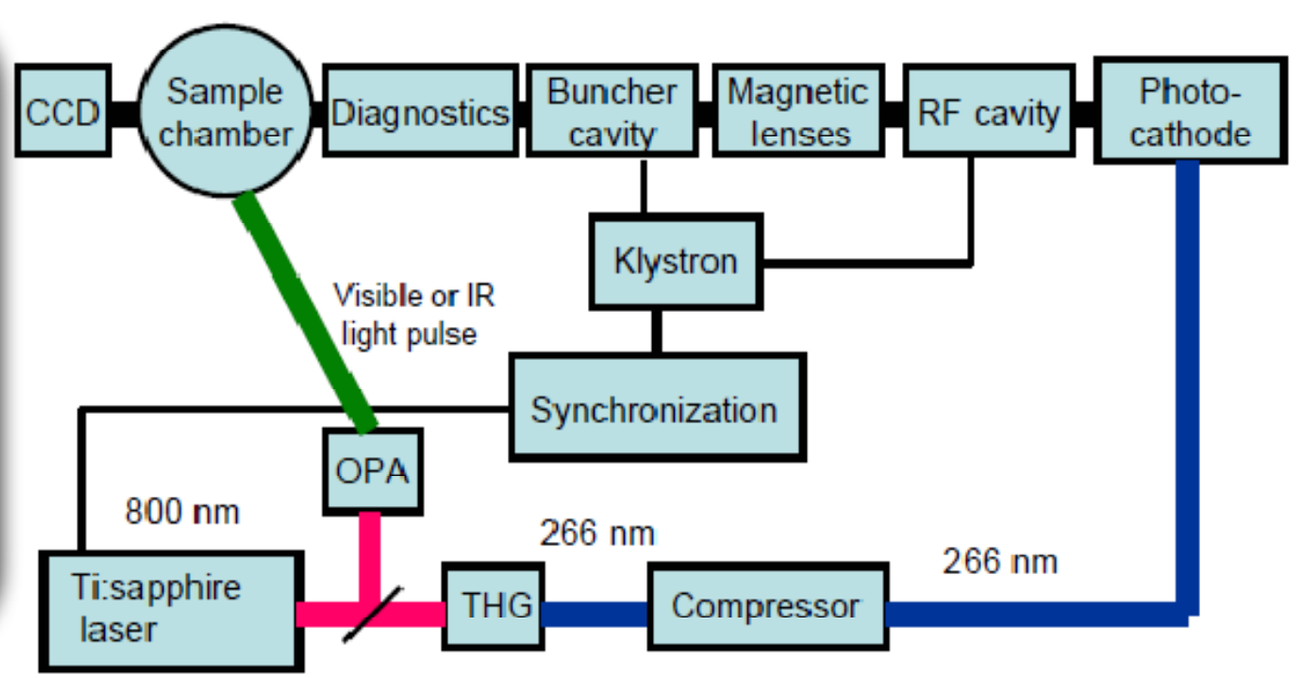
$\triangle E = 33$ keV

$\tau = 14$ fs RMS

$\epsilon_n = 0.3$ mm mrad

$\sigma_{trans} = 8.5$ μm RMS

$Q = 1$ pC



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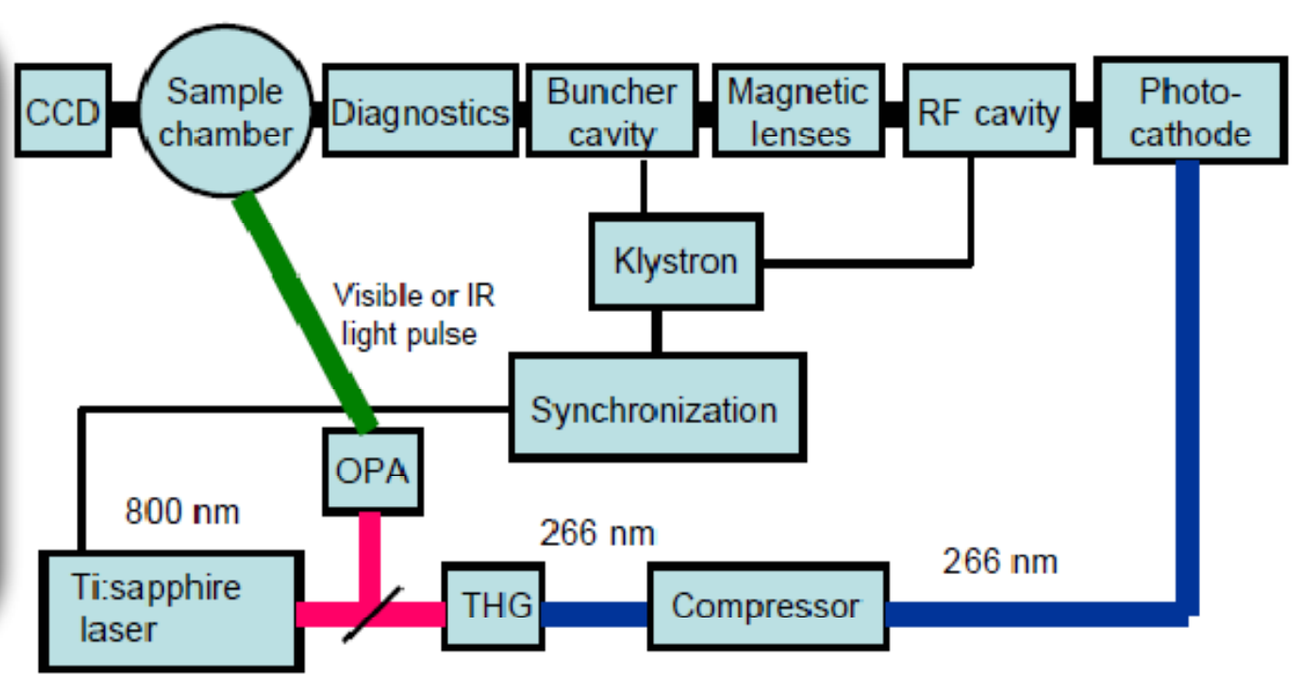


Courtesy of D. Miller

200 TW laser

- 200 TW laser characteristics:
  - Ti:sapphire CPA system: 5 J in 25 fs.
  - synchronised to within 10s fs of REGAE beam.
- Quasi-linear regime with $a_0 \sim 1$ to avoid self-injection.

Target

- Gas cell/Capillary discharge waveguides
  - Larger wakefield than REGAE electron bunch size $\longrightarrow$ $n_e \sim 1 \times 10^{17}\ \mathrm{cm}^{-3}$

Spence and Hooker, Phys. Rev. E, 63, 015401 (R)

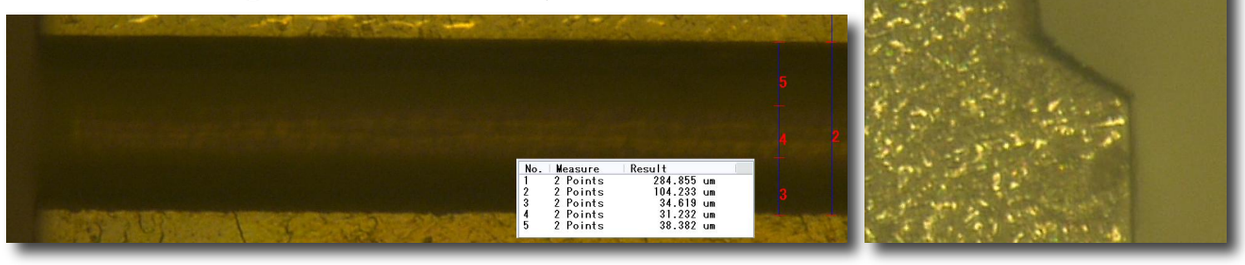
Target

- Gas cell/Capillary discharge waveguides
  - Larger wakefield than REGAE electron bunch size $\longrightarrow$ $n_e \sim 1 \times 10^{17}\ \mathrm{cm}^{-3}$
  - In-house laser machining of sapphire capillaries.
  - Freedom to produce custom density profiles.

Microscope images of half-capillary with diameter: $100\ \mu\mathrm{m}$

Transverse view

Longitudinal view



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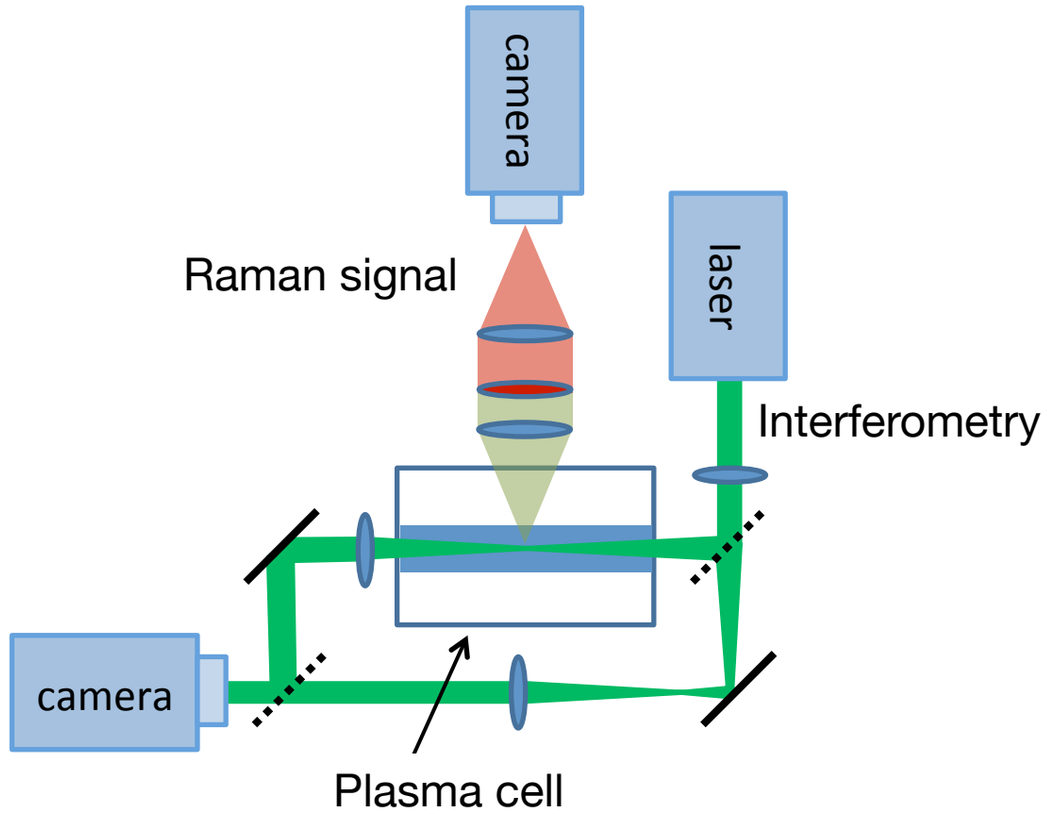
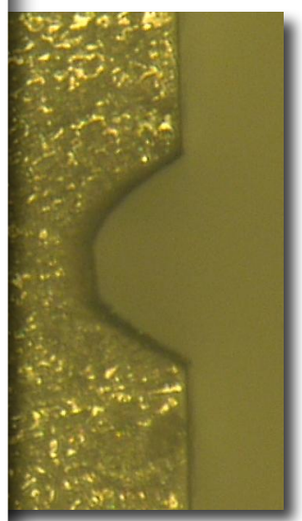
Target

- Gas cell/Capillary discharge waveguides
  - m^{-3}
  - Confirmed Raman signal at densities as low as $n_e = 5 \times 10^{17}\ \mathrm{cm}^{-3}$.

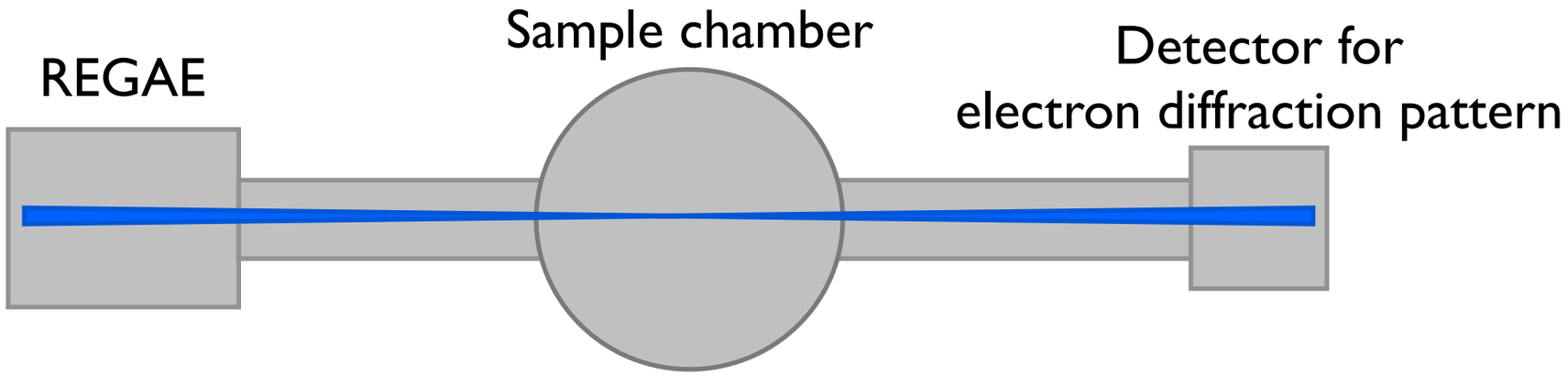




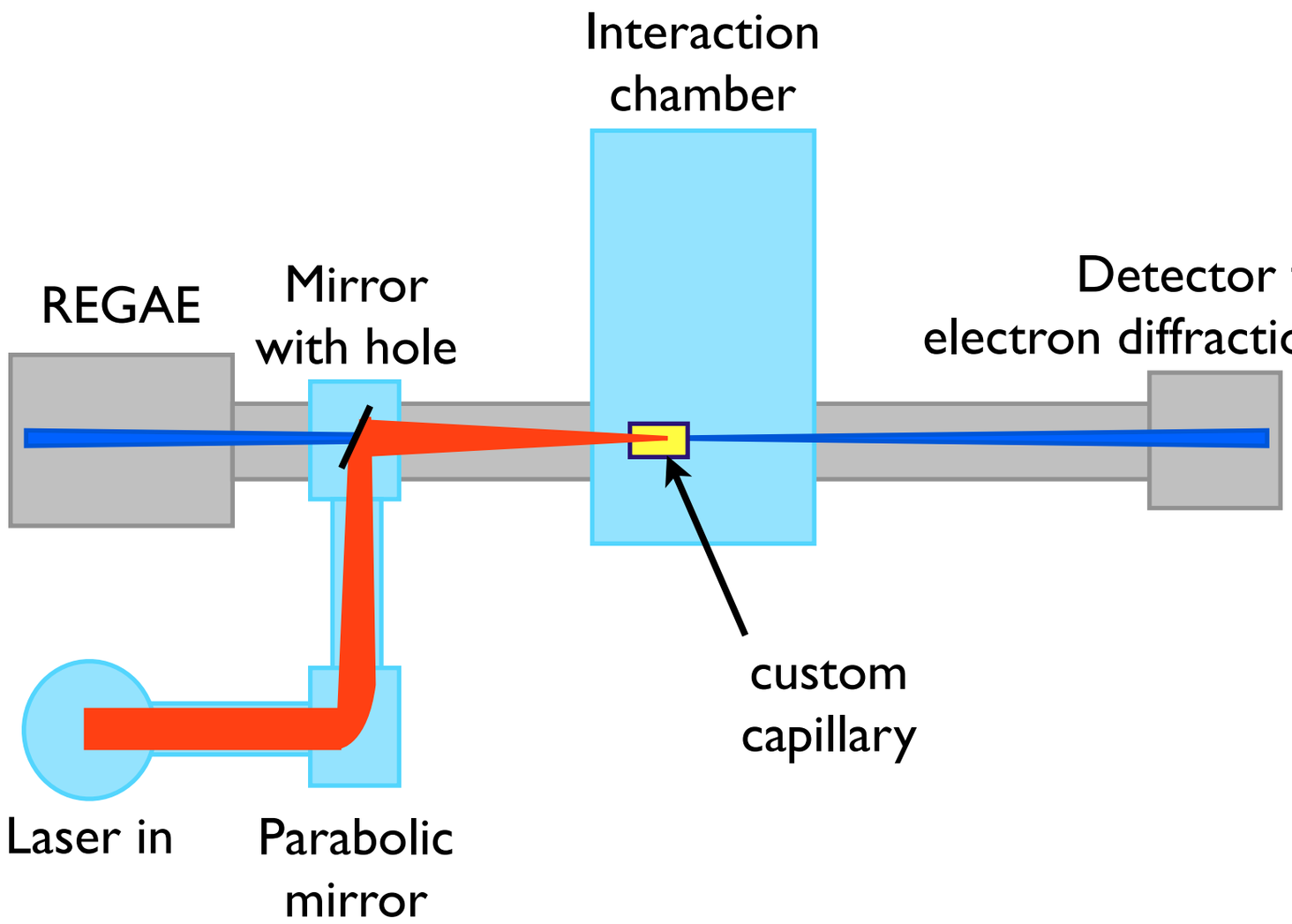
Weineisen et al., Phys. Rev. ST Accel. Beams, 14, 050705 (2011)

Spence and Hooker, Phys. Rev. E, 63, 015401 (R)

Current setup

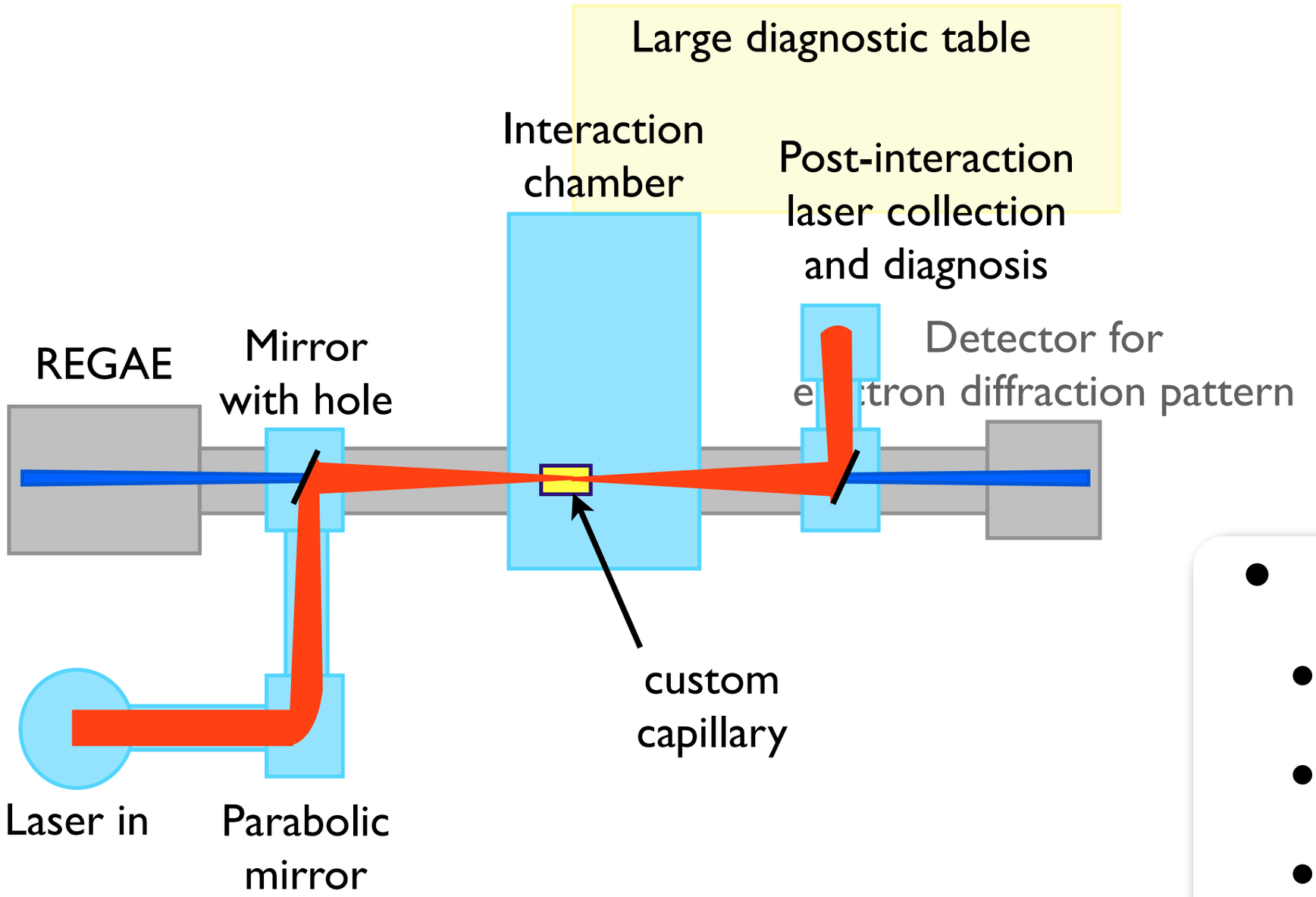


Modified setup



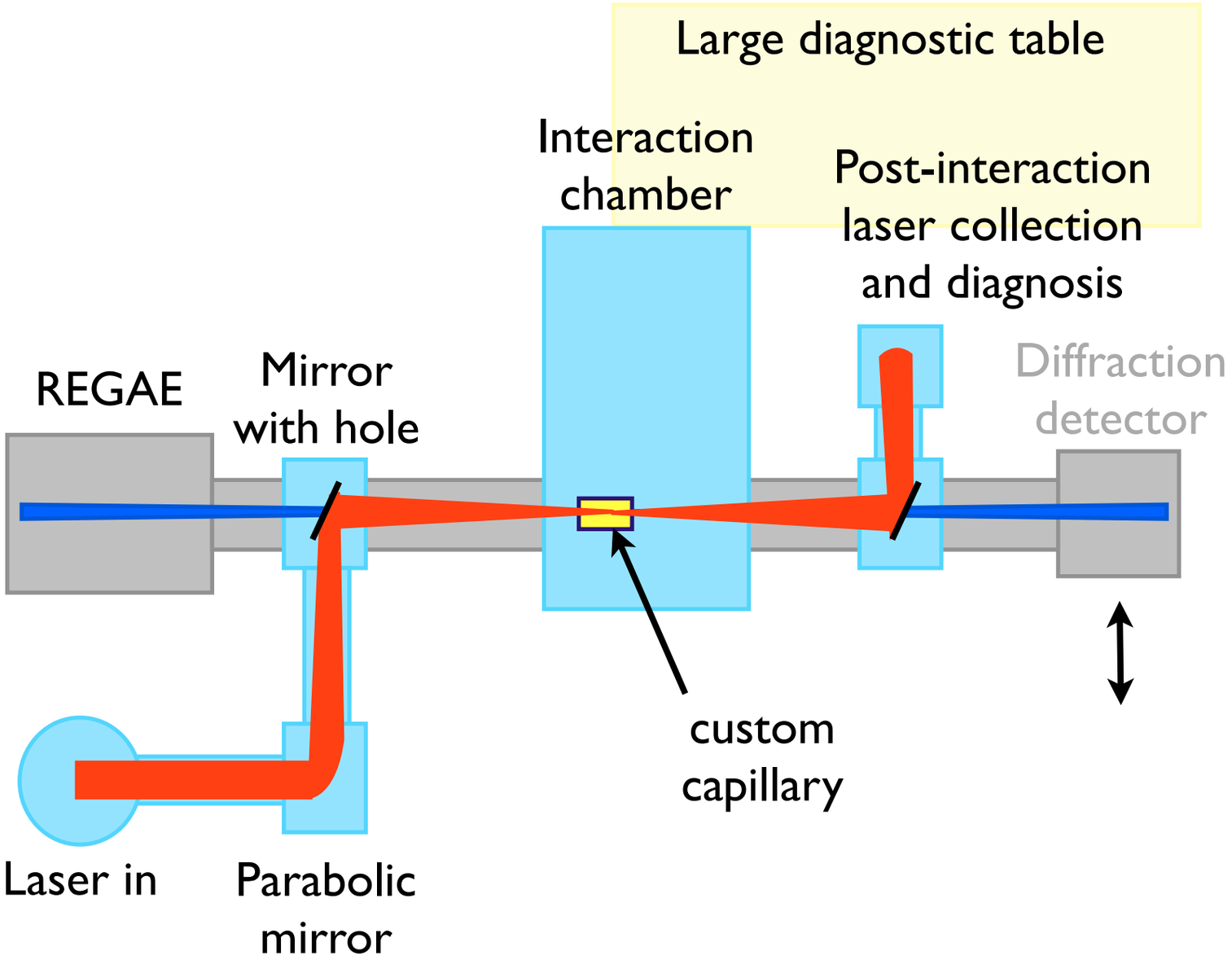
- Plasma diagnostics:
  - Density measurement
  - Faraday rotation
  - Thomson side scatter
  - Transverse probing
  - ….

Modified setup



- Laser diagnostics:
  - Transmitted power
  - Transmitted spectrum
  - Autocorrelation
  - ….

Modified setup



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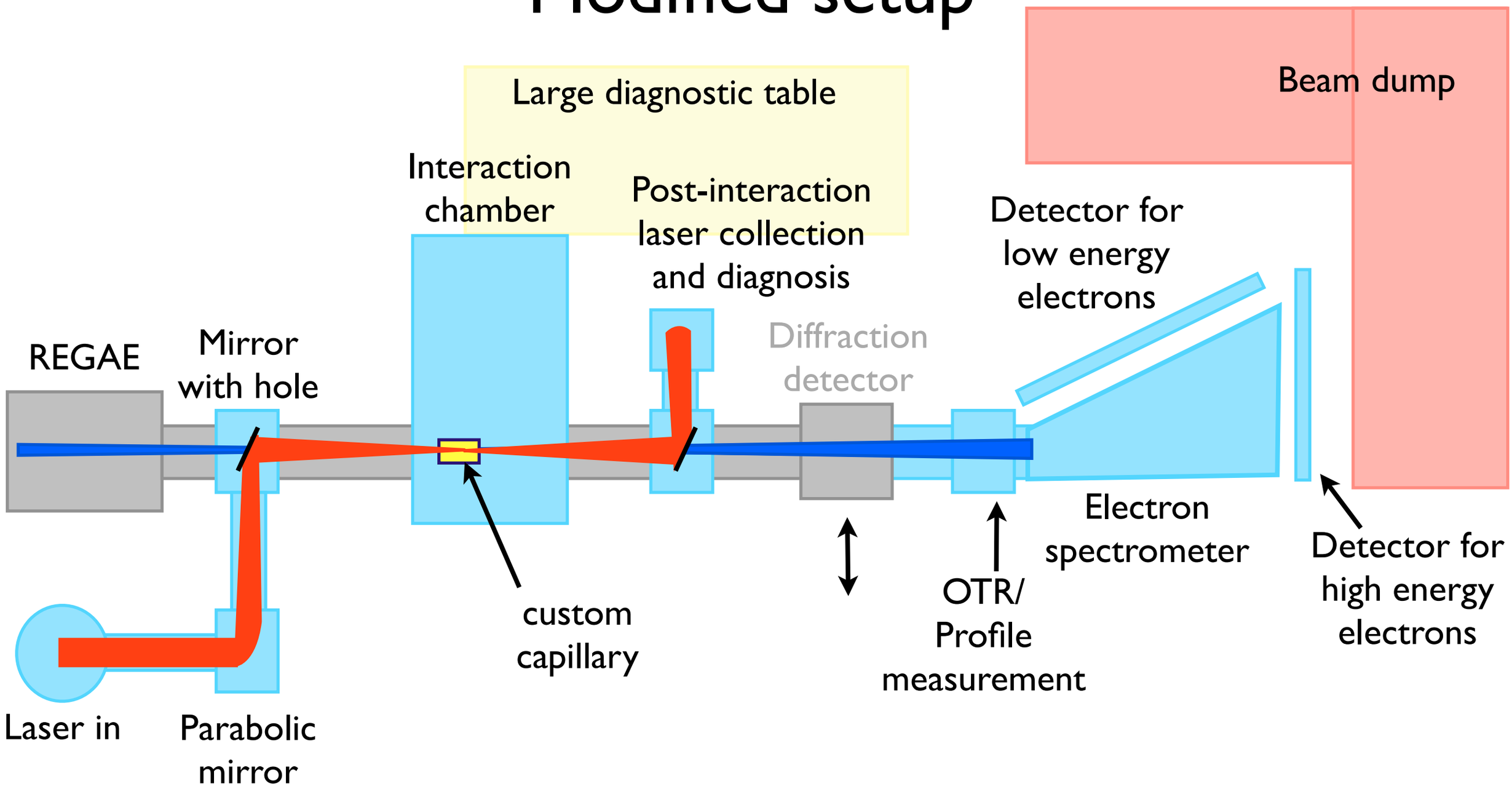
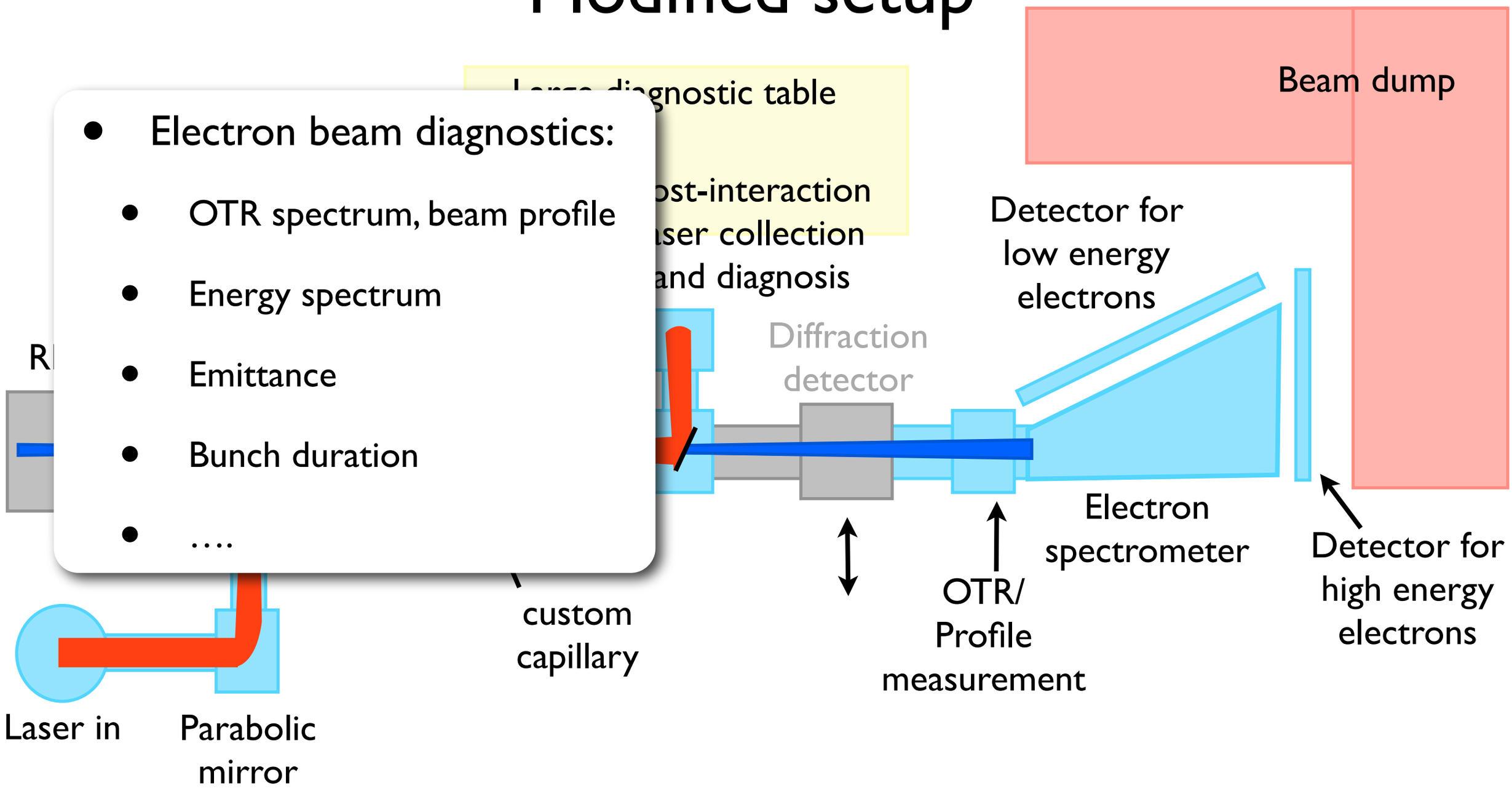


Modified setup

- Electron beam diagnostics:
  - OTR spectrum, beam profile
  - Energy spectrum
  - Emittance
  - Bunch duration
  - ….



Experiments

- Mapping fields of the wake
- Emittance evolution
- Bunch compression
- Laser-only beamline

Currently a dedicated theory team is working closely with IST on OSIRIS PIC simulations identifying potentially interesting avenues for experimental investigation.

3D particle-in-cell (PIC) simulation

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3D particle-in-cell (PIC) simulation

- Bunch compression

- Laser-only beamline
  - Controlled injection
  - Light-source development

Summary

- External injection of short electron bunches into preformed wake.
- Unique facility:
  - REGAE: 1 pC, 5 MeV, 14 fs.
  - 200 TW laser: 5 J, 25 fs pulse.

  } Synchronised
- Deeper understanding of electron acceleration in a wakefield
  - Mapping wake, emittance evolution, bunch compression …
  - Controlled injection.
  - Light source development.

Acknowledgements

Plasma accelerator group:

Jens Osterhoff - Head of Group

Julia Grebenyuk, Timon Mehrling } PIC simulations

Lucas Schaper, Tobias Kleinwaechter } Gas target development and characterisation

Jan Patrick Schwinkendorf - Capillary machining

Maria Kuhn - 3D fluid model development

Accelerator physics group:

Florian Gruener - Head of the 'Accelerator Physics Group'

Benno Zeitler - Electron beam diagnostics

Matthias Schnepp - Laser engineer

REGAE:

Klaus Floettmann - REGAE

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Thank you for listening.
Merry Christmas!