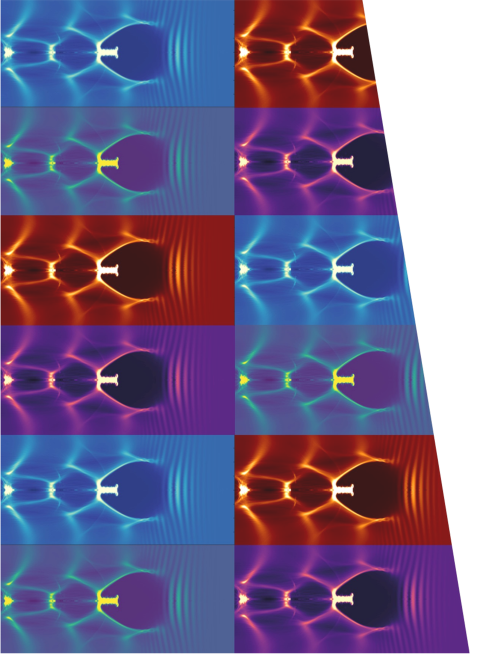

A plasma accelerator driven by an industrial Yb:YAG laser at kHz repetition rate

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Industrial applications call for industrial lasers

Laser plasma accelerators working at **kHz repetition rate** [1, 2, 3, 4, 5] can be disruptive in a wide range of applications:

- Time resolved studies
- Imaging and medical treatment
- Industrial processing

Industrial lasers are turn-key systems which deliver milliJoule pulses and can be extremely useful for the goal:

- High repetition rate
- Reliability
- Stability

Down to the few-cycle regime

Few femtosecond pulses are needed to reach the desired peak intensity with milliJoule energies

Post-compression techniques allow to compress pulses beyond their initial transform limited duration [6]:

- Spectral broadening
- Dispersion compensation

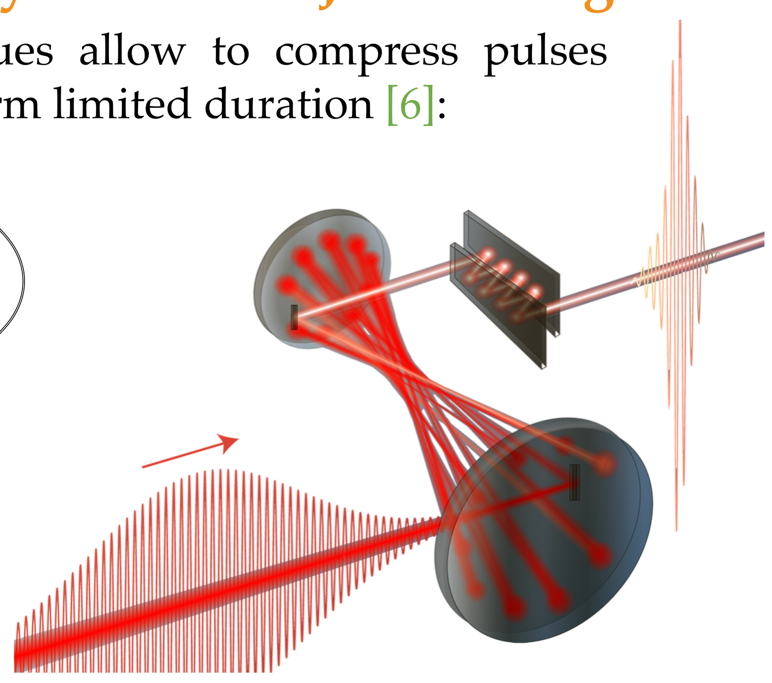

Fig 1: General scheme of a multi-pass cell (MPC) post-compression setup.

Bubble regime with mJ pulses

PIC simulations show promising results

Once compressed, few-mJ, few-fs pulses can efficiently drive electron acceleration in the bubble regime [7]. Energies **up to 20 MeV** can be achieved with 6 mJ, 10 fs pulses.

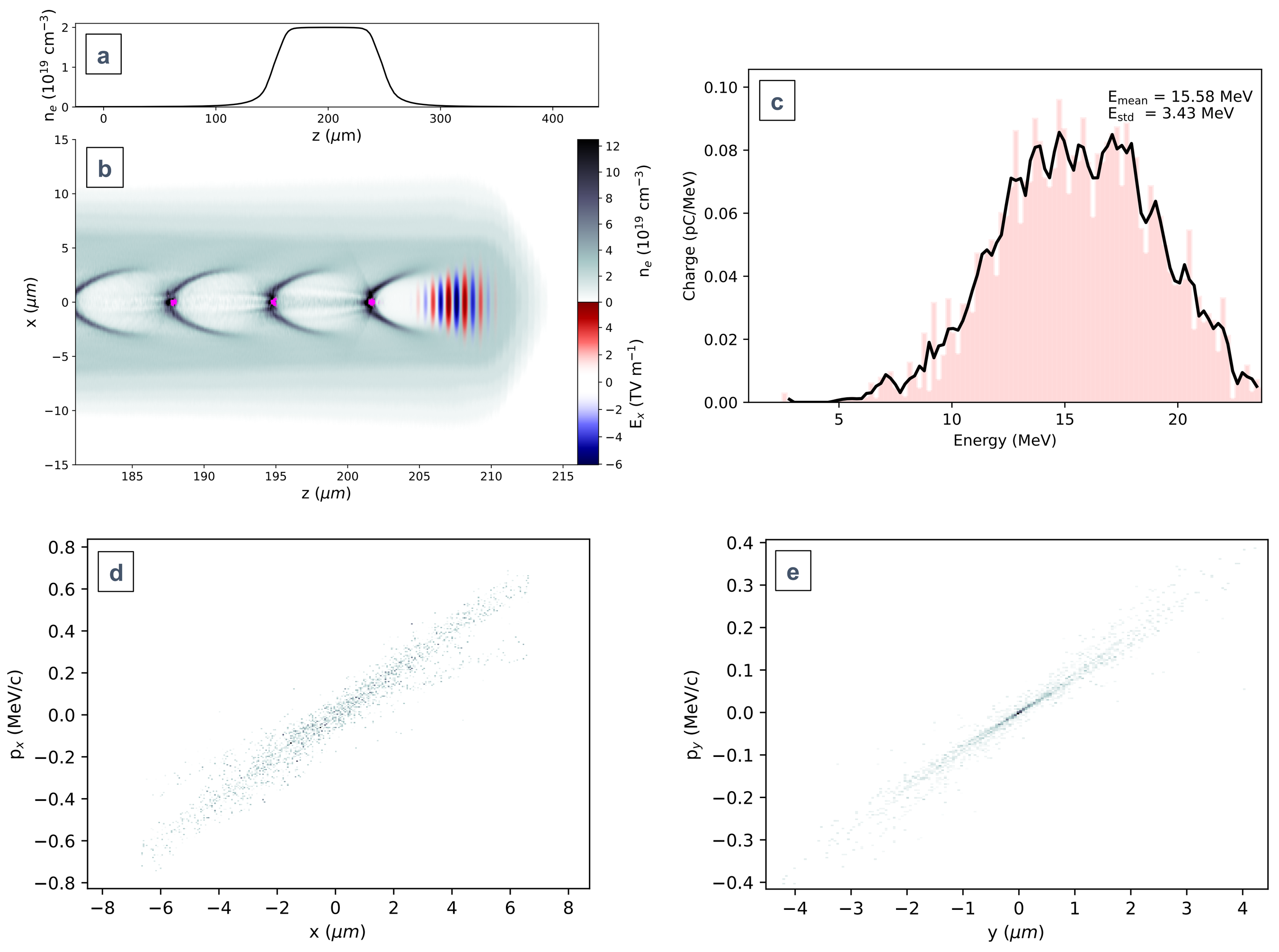

Fig 2: PIC simulation (FBPIC) showing the obtainable electrons parameters with a 6 mJ, 10 fs pulse. Panel (a) represent the plasma density profile along the propagation direction, panel (b) shows the wake evolution and the injected electrons (pink), panels (c), (d) and (e) depict the obtained electron spectrum at the end of the propagation (~100 μm after the source) and the x-y phase space.

Approaching the terawatt regime with an Yb:YAG laser

A record compression factor > 100 recently achieved in a double multipass-cell setup

Pulse compression happens in two separate stages. In each one, **self-phase modulation** in gas (stage 1: argon, stage 2: neon) is exploited to broaden the pulse spectrum, followed by a dispersion compensation line (**chirped mirros** pairs and wedges) to obtain the actual temporal compression [8].

Initial output:
- τ ~ 1.2 ps
- E ~ 9.5 mJ

→

Compressed output:
- τ ~ 9.6 fs
- E ~ 6.7 mJ

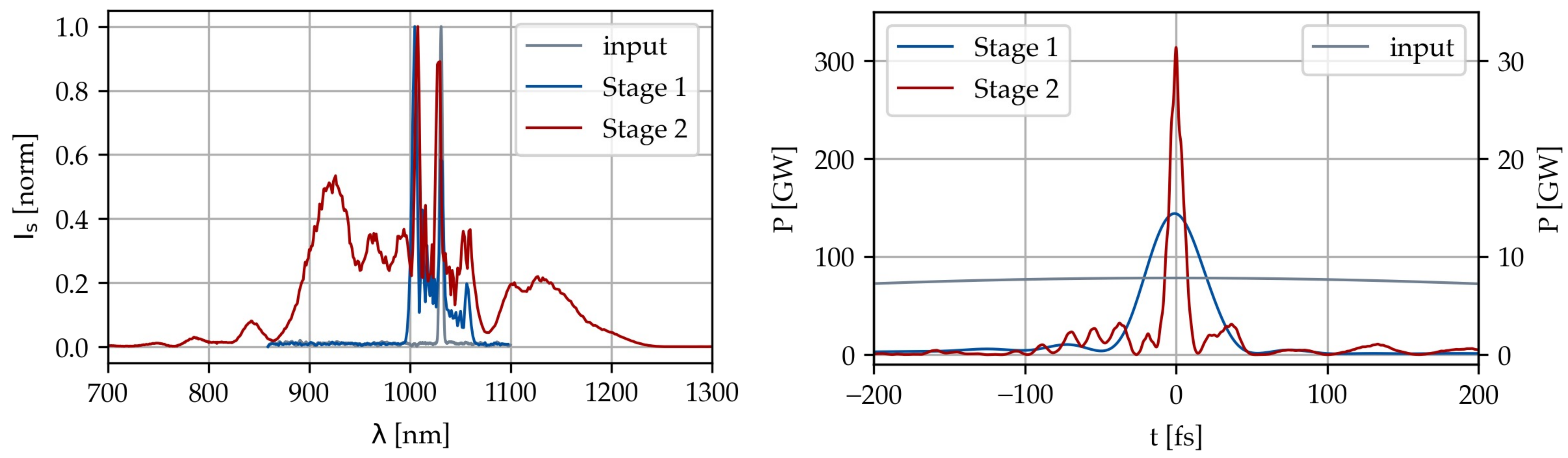

Fig 3: Measured spectra for each compression stage (left) and corresponding FROG-retrieved temporal profile (right). The output of the first compression stage is shown in blue, the one of the second in red. The initial laser output is depicted in grey. After the second compression stage a peak power > 300 GW is reached.

Towards the first few-MeV electron acceleration

A tunable, reproducible laser red-shift shows, for the first time, evidence of a plasma wave being excited by an industrial Yb:YAG laser

Laser spectral shifts can be a measure of the energy transferred to the plasma [9] and are a fundamental tool to achieve the first electron acceleration.

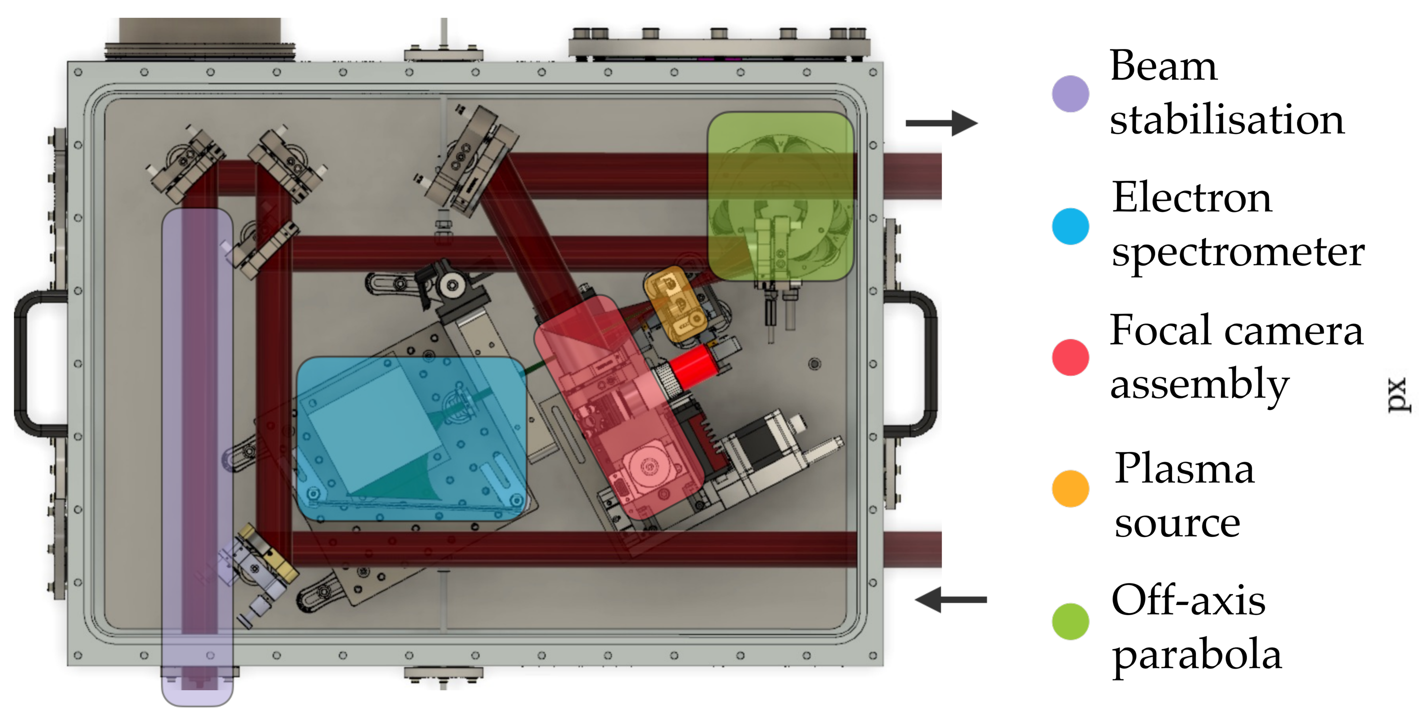

Fig 4: Scheme of the acceleration chamber. The main parts of the setup are enlighten in different colours.

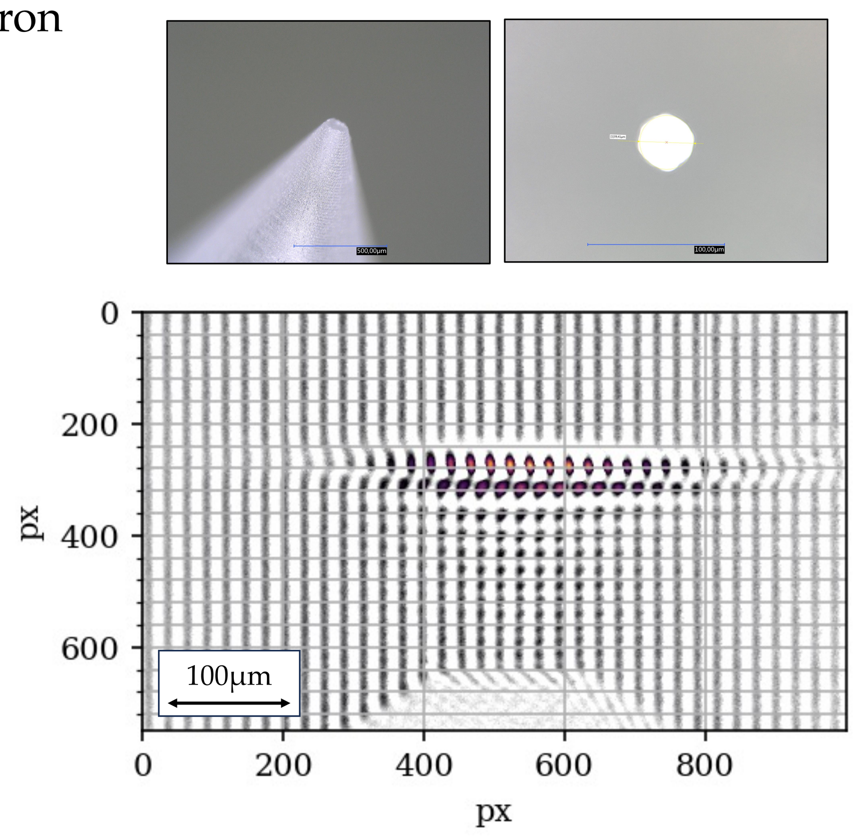

Fig 5: A typical interferogram used for the plasma density characterisation. The glass de Laval nozzle, visible on the bottom, has an output diameter of only 120μm and a throat of 40μm, as shown in the microscope images on top.

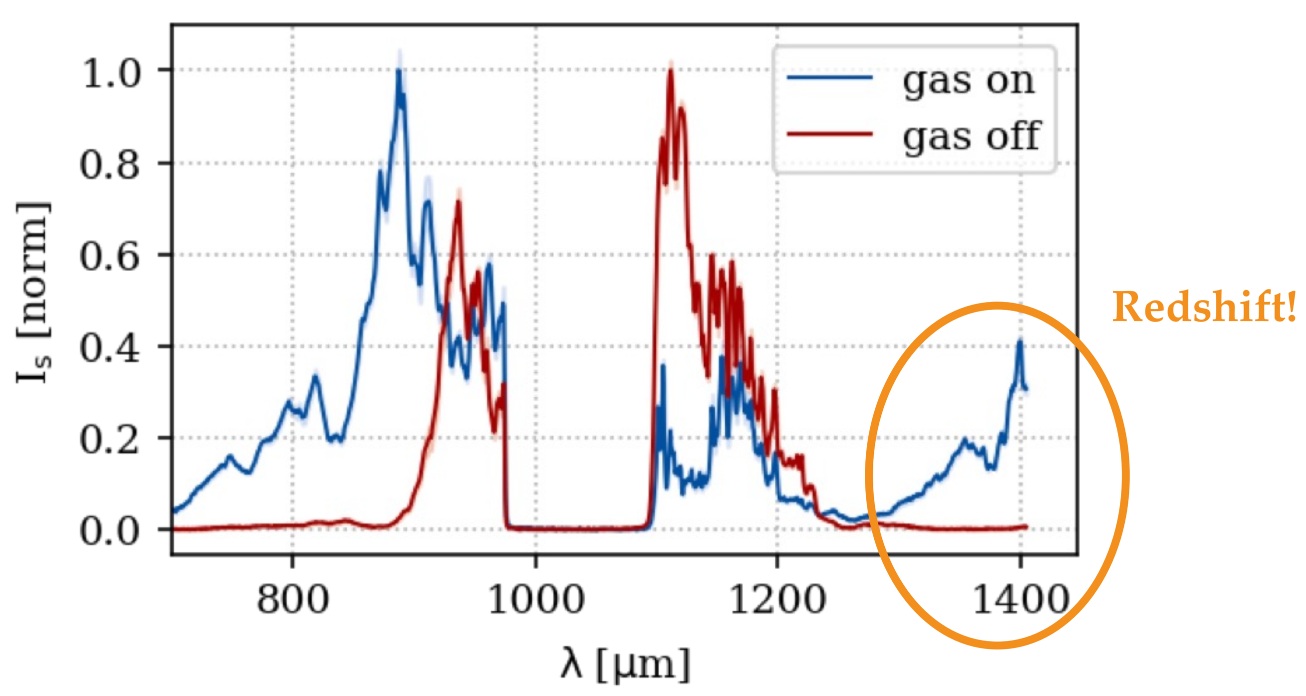

Fig 6: Laser spectra after the interaction point. The central wavelength (1030nm) has been filtered out for better visibility. The spectrum after the laser-plasma interaction (blue) is compared to the initial laser spectrum (red). Spectral shifts on both sides of the spectrum are evident.

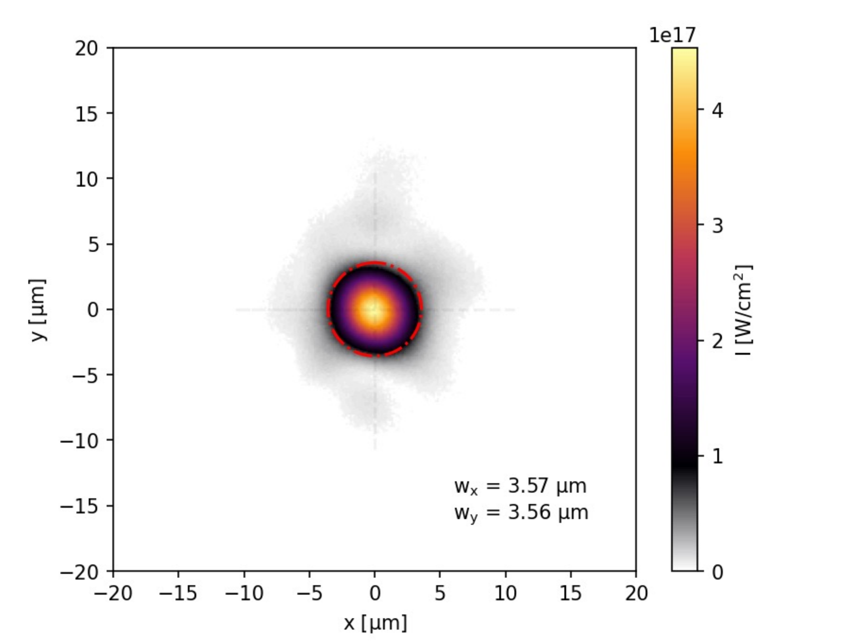

Fig 7: Measured laser focal spot and relative intensity profile at the interaction point. The gaussian fitting (in red) shows a circular spot with 3.5μm radius.

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