BostonElectronics Lytid

Application note

Beam characteristics -TeraCascade 2000

The Tera Cascade QCL source provides a high power, highly coherent and quasi-gaussian laser beam. The latest, being a critical criterion for imaging, beam shaping or other sensing techniques, is detailed in this application note.

The following characterization have been realized in a non-controlled environment displaying temperatures variations higher than 1°C, variation of the hydrometric level up to 5% over the typical measurement's times and ambient lightning in order to reproduce typical operating conditions.

The following measurements have been performed using two optical setups. The first one (see figure 1.a) consist of a Φ1" f/1 coated HRFZ-Si lens for the beam collimation and a Φ1" f/2 coated HRFZ-Si lens for focusing while two Φ2" f/1 golden parabolic mirrors are used for the second one (see figure 1.a), leading to higher focusing angle and so spot size.

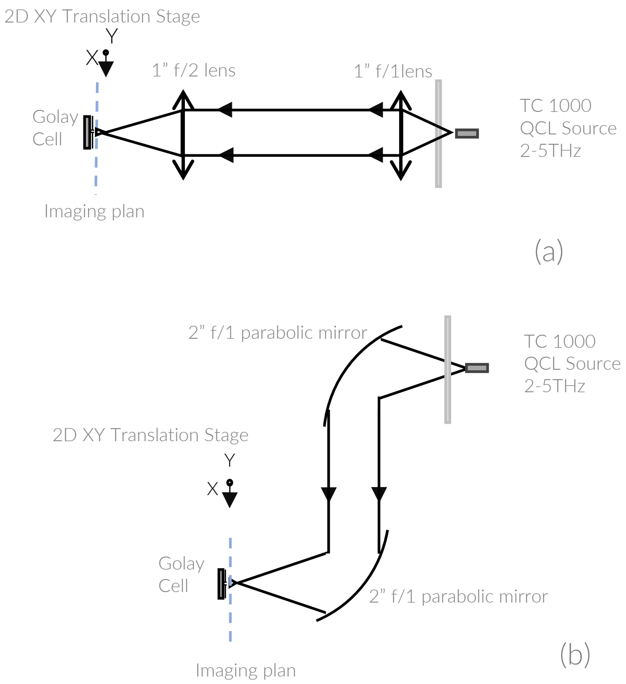

Figure 1 Optical setups schematics

A sensitive Golay cell detector, with a pinhole aperture, mounted on a motorized 2D translation stage for raster scan, is placed behind the optical setup around the focus point. A lock-in amplifier is used to recover proper signals and sensitive amplitudes variations at each point measurement over the area of interest.

Near gaussian beam profile of the focused beam

A perfect gaussian beam intensity distribution profile is dictated by the following equation.

$$I(r) = I_0(z)e^{\frac{-2r^2}{w^2(z)}}$$

The beam radius, ω(z), element of interest in this note, is defined as the distance for which the electric field amplitude is decreased by a factor of 1/e and so the intensity by a factor of $1/e^2$ as illustrated on Figure 2.

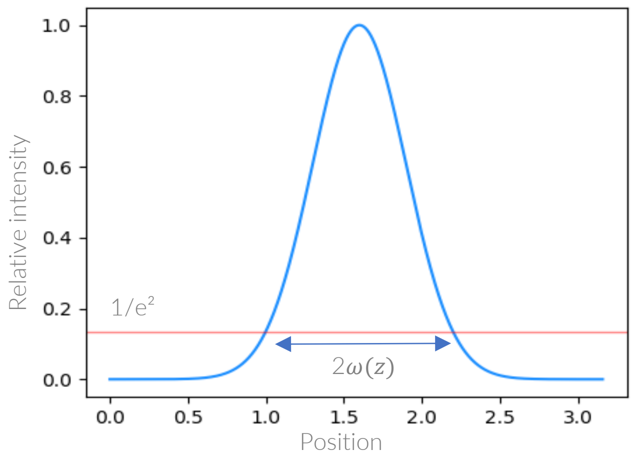

Figure 2 Theoretical gaussian beam distribution

At the optimum focalization position, the beam spot size is minimal and called the waist radius, ω_0.

The following figures display the 2 dimensions beam profiles at the waists of the two optical setups as well as their respective cross sections completed with their theoretical gaussian profiles.

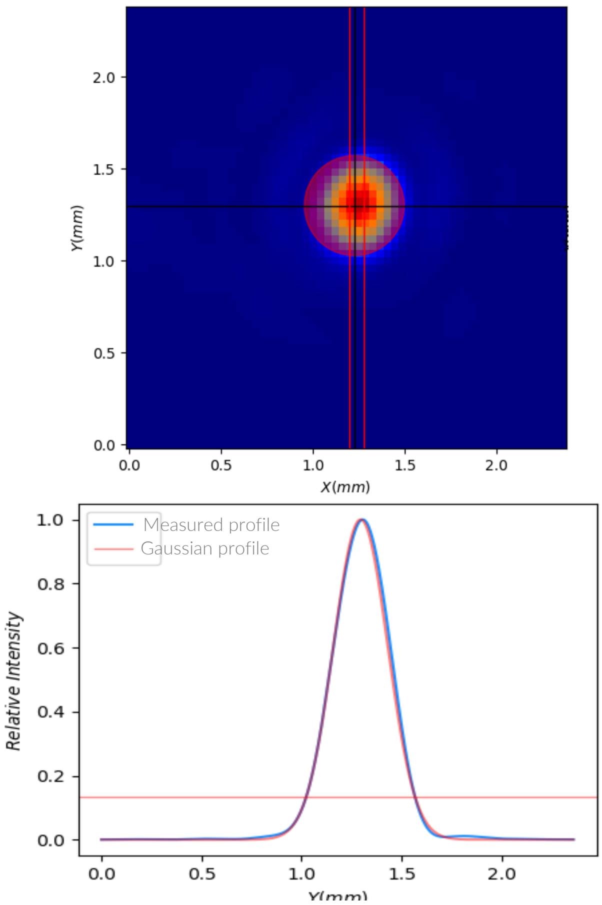

Figure 4 Beam profile at the lenses optical setup's waist

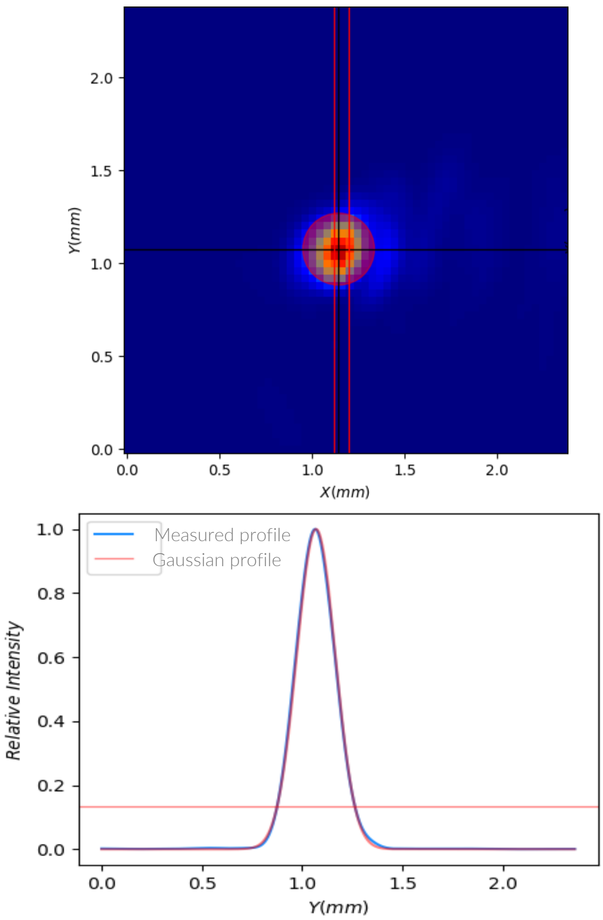

Figure 3 Beam profile at the parabolic mirrors optical setup's waist

A 0.27mm waists radius have been obtained for the lens setup, while, thanks to the larger focusing angle, a $1/e^2$ radius of 0.19mm is reached using the parabolic mirrors optical setup.

Gaussian beam propagation

Beside the spot profile study, a gaussian beam follows a proper propagation scheme. In the case of a perfect first order gaussian beam, its $1/e^2$ radius along the propagation direction, z, is

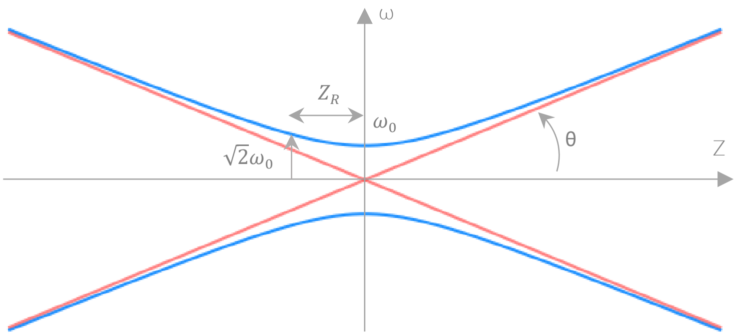

Figure 5 Beam diameter propagation

dictated by the following equation and is illustrated in Figure 4.

$$\omega(z) = \omega_0 \sqrt{1 + \left(\frac{\lambda z}{\pi \omega_0{}^2}\right)^2}$$

The propagation proprieties of a gaussian beam can dictate the optimum spot dimensions that can be achieved using a source according to a given optical setup.

The Rayleigh distance Z_R is the distance from the waist for which the radius has been multiplied by a factor of $\sqrt{2}$. It gives an order of magnitude of the range for which the beam keeps a relatively constant diameter and can be expressed as follows:

$$Z_R = \frac{\pi \omega_0{}^2}{\lambda}$$

A direct link between the far field divergence of the beam (θ for z>>Z_r) and its waist radius (minimum radius) can also be derived and is given by the following equation.

$$\Theta = \frac{\lambda}{\pi \omega_0}$$

In the case of non-first order gaussian beams or imperfect gaussian beams, a quality factor M^2 is introduced in order to account for the higher order diameters that are given by $\omega_{mn}(z) = M\,\omega_{00}(z)$ with M constant. The beam radius propagation equation is then changed as follows:

$$\omega(z) = w_0 \sqrt{1 + \left(\frac{M^2\, \lambda\, z}{\pi\, {\omega_0}^2}\right)^2}$$

The M^2 factor is given by the ratio of the measured divergence angle with respect to the theoretical angle calculated from the measured waist size.

$$M^2 = \frac{\Theta}{\frac{\lambda}{\pi \omega_0}}$$

Knowing the M^2 factor of a source, it is then possible to derive the minimum spot size on an optical setup for a given divergence and vice versa.

The two following figures display the results for the M^2 factor measurements performed using the TeraCascade 1000 series 2.5THz chip with both optical setups. The raw measurements points have been completed by the theoretical propagation profile that take into account their respective calculated M^2 factors.

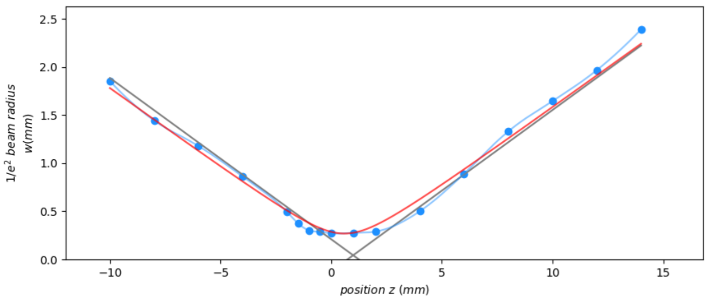

Figure 6 Beam propagation for the lenses optical setup

In the case of the lenses optical setup, the M^2 factor of 1.17 for a divergence of 166mrad (9.5°) ensures a quasi-diffraction limited beam, highly suitable for high quality imaging systems or sensing setups and proper beam shaping.

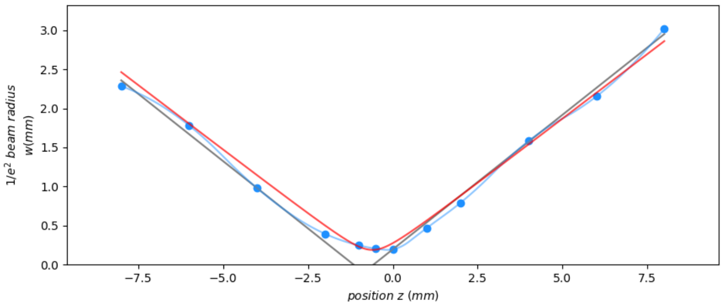

Figure 7 Beam propagation for the parabolic mirrors optical setup

The higher M^2 factor of 1.62 obtained by the mirror optical setup could be explained by the larger focusing aperture of 331mrad (19°) used in this setup, leading to much more sensitive alignment requirements.

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