πShaper 6_6 / 7_7

Laser Beam Shaping Optics

Manual

January 12, 2024

1. *Specification*

Table 1

Common for all πShaper 6_6 and 7_7 models:	
Type	Field mapping beam shaper as a telescope of Galilean type, without internal focus
Input beam	- Collimated - TEM_{00} or multimode with Gaussian or similar intensity profile
Output beam	- Collimated - Flat-top, uniformity within 5% - Diameter ~6-7 mm - High edge steepness
Other features	- Achromatic for design wavelengths - Compact design suitable for scientific and industrial applications - Conserving flatness of the beam wavefront - Long working distance
Overall dimensions	- Diameter 39 mm - Length <143 mm
Weight	< 250 g
Mounting	External Thread M 27x1, at Input and Output

***πShaper* features**

Model	Input $1/e^2$ Dia, mm	Output FWHM Dia, mm	Optimum spectrum*, nm	Design wavelengths, nm	Applications based on
7_7_10.6	7.0 - 7.1	7.0	10000 - 11000	10600	CO_2 lasers
7_7_9.4			9000 - 10000	9400	CO_2 lasers
7_7_5.1	7.0 - 7.1	7.0	5000 - 5500	5300	CO lasers
6_6_NIR	5.9 - 6.0	6.0	1100 – 1700 achromatic	1319, 1650	near IR Laser
6_6_VIS	5.9 - 6.0	6.0	405 – 680 achromatic	442, 632.8	He-Ne, He-Cd and other lasers of visible spectrum
6_6_NUV	5.9 - 6.0	6.0	335 – 560 achromatic	355, 532	2nd, 3rd Harmonics of Nd:YAG, UV and Violet lasers
6_6_1.9-2.8	6.1 - 6.2	6.4	1900 - 2800	2050	mid-IR Lasers
6_6_2.05	6.4 - 6.5	6.4	1900 - 2160	2050	mid-IR Lasers
6_6_1550	6.4 - 6.5	6.2	1500 - 1600	1550	near IR Lasers
6_6_1064	6.4 - 6.5	6.1	1020 - 1100	1064	Nd:YAG, Fiber and other near IR lasers
6_6_TiS	6.4 - 6.5	6.0	700 - 900	800	Ti:Sapphire, Diode Lasers, other near IR lasers
6_6_532	6.3 - 6.4	5.8	510 - 550	532	2nd Harmonics of Nd:YAG and similar lasers
6_6_350	6.3 - 6.4	5.6	330 - 380	355	3rd Harmonics of Nd:YAG and similar lasers
6_6_325	6.3 - 6.4	5.6	305 - 345	325	UV He-Cd laser
6_6_266	6.3 - 6.4	5.2	250 - 275	266	4th Harmonics of Nd:YAG and similar lasers
6_6_213	6.3 - 6.4	5.2	206 - 220	213	5th Harmonics of Nd:YAG and similar lasers

* - according to coatings applied

2. Description

The ***πShaper_6_6*** and ***πShaper_7_7*** series of beam shaping systems represent optical components for converting input single mode beams (TEM_{00}) or multimode beams, the intensity profile of which is similar to Gaussian, into flattop beams with a uniform intensity distribution. Due to many of the same properties, the generic name ***πShaper*** is used below, if necessary, differences between models will be noted additionally.

The *πShaper* are field mapping beam shapers implemented as telescopes with two optical components, Fig.1, top. It is implied that wavefronts at the input and output are flat; the transformation of the intensity profile from Gaussian to uniform is realized in a controlled manner, by accurate introducing wave aberration by the 1st component and further compensation by the 2nd component.

Thus, the resulting collimated output beam has a uniform intensity and a flat wave front; it is characterized by low divergence – almost the same as that of the input beam. In other words, the field mapping beam shapers *πShaper* transform the intensity distribution *without violating the integrity of the beam and without increasing its divergence*.

In short, the main features of the refractive field mappers are:

- refractive optical systems transforming Gaussian to flat-top (uniform) intensity distribution;
- transformation through controlled phase front manipulation – the 1st component introduces the spherical aberration necessary for energy redistribution, and the 2nd component compensates for the aberration;
- the output beam is free from aberrations, the phase profile is maintained flat, hence, low output divergence;
- TEM_{00} and multimode beams applied;
- collimated output beam;
- the beam profile remains stable over large distance;
- implementations in the form of telescopic optical systems; achromatic optical design - beam shaping for several lasers simultaneously;
- Galilean design, no internal focusing.

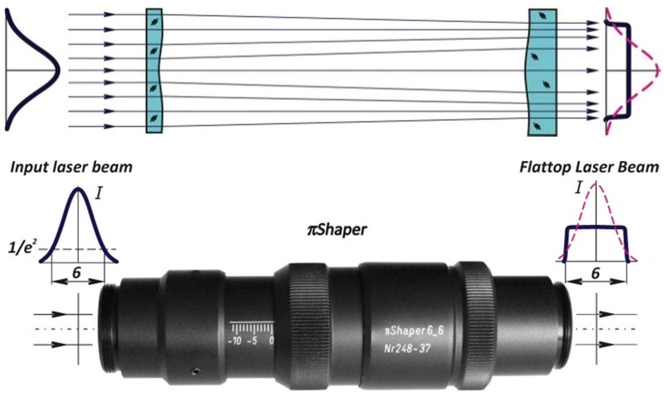


Figure 1. Refractive field mapping beam shaper *πShaper.*

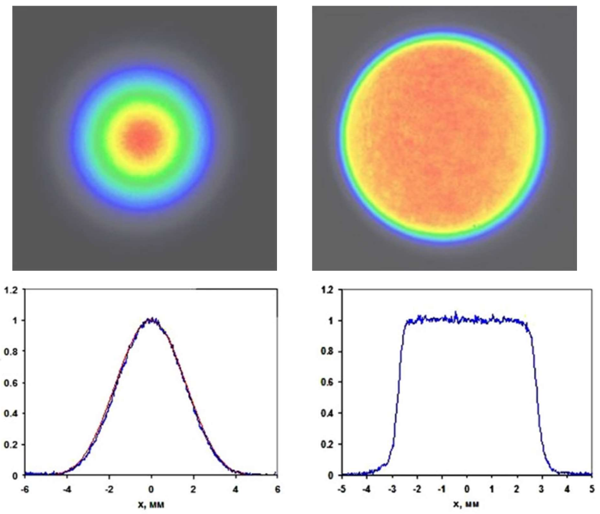


Figure 2. Beam shaping of the TEM_{00} laser, the measured intensity profiles: on the left – Input TEM_{00} beam, on the right - after the *πShaper*.

The operation of *πShaper* is presented in Fig.1 and 4, example of beam shaping – in Fig.2.

The Angular Magnification of the telescopic system is about 0.65, therefore, from the point of view of paraxial optics, the diameter of the output beam is increased by factor 1/0.65, and the field of view angle is reduced by factor 0.65.

The optical system of the *πShaper* consists of 2 components with the clear apertures (CA) given in Table 2.

The input and output sides of the *πShaper* are shown in Fig. 3; the adjustment rings are always located closer to the exit.

Table 2

Model	Clear aperture (CA), mm	
	Input	Output
πShaper_6_6	~10	~8
πShaper_7_7	12	10

Figure 3. *πShaper* side view.

3. *Input beam*

The optical design of *πShaper* assumes that the input beam is TEM_{00} or multimode with the Gaussian-like or parabolic Intensity profile, see example in Fig.2. The input beam is to be **collimated** and have an $1/e^2$ intensity diameter 2ω = ~6 mm for the *πShaper* 6_6 (ω is the beam waist) and 2ω = ~7 mm for the *πShaper* 7_7, the exact data for particular models are given in Table 1.

Figure 4. *πShaper* operation.

The Clear Apertures of the input optical components are more than 1.5 times larger than the optimum 2ω, therefore, theoretically 99% of the Gaussian beam passes through the optics.

One of the *πShaper* components, on the output side, is movable; this is to compensate for the divergence/ convergence of the input beam. The full compensation range is ±4 mrad, which is an order of magnitude greater than the natural divergence of laser beams of ~6 mm $1/e^2$ diameter and wavelength <2µm, see the chapter "Features of mechanical design".

Notes: Variation of the input beam size results in a variation of output profile!
Deviation of the input beam profile from the Gaussian function also results in a variation of the output profile!

To evaluate the intensity distribution, it is strongly recommended to use dedicated instruments,
for example, camera-based beam profilers!
Do not use the Scanning Slit beam profilers!

When building optical systems with πShaper, it is highly recommended to provide the ability to adjust the diameter of the input beam with control of the output beam profile.

4. *Output beam*

In accordance with the principle of operation, the output beam is collimated and has a uniform intensity profile, the theoretical deviation from uniformity is less than 2%.

The wavefront error (wave aberration) is less than ±λ/10.

Depending on the structure of the input beam, a uniform output profile remains stable at a distance of about 150 – 200 mm. With further propagation in space, owing to diffraction effects, the intensity profile of a flat-top beam of a single phase front (TEM_{00} input) is transformed into a non-uniform beam with the Airy disk distribution in the far field. The behavior of multimode beams is more complex and strongly depends on the properties of the input beam; typically, it is transformed in the far field back into a Gaussian-like or parabolic profile.

See detailed descriptions, as well as methods for overcoming diffraction effects using imaging in the article

"Imaging techniques with refractive beam shaping optics"
http://www.pishaper.com/pdfs/spie2012_imaging_tech_refract_beam_shaping_optics.pdf

Variation of the input beam size results in a variation of output intensity profile!

A comparison of the output intensity profiles is presented in the Appendix in the chapter "πShaper 6_6_VIS Variation in the output intensity profile with a variation of the diameter of the TEM_{00} Gaussian input beam".

Typically, the tolerance for input beam diameter is ±5%.

Variation of the input beam intensity distribution results in a variation of the πShaper output intensity profile!

To ensure a uniform distribution of the output intensity, it is necessary to adapt the size of input beam; examples of such adaptation are presented in the Appendix in the chapter "πShaper 6_6_VIS Providing a flat-top output profile with input beams which profiles deviate from the Gaussian function".

The effect of changing the profile of the output beam by changing the size of the input beam can be used to compensate for the deviation of the profile of the input beam from the ideal Gaussian!

Note: To evaluate the intensity distribution, it is strongly recommended to use dedicated instruments,
for example, camera-based beam profilers!
Do not use the Scanning Slit beam profilers!

5. *Spectral properties*

The optical components of the *πShaper* are made of fused silica or ZnSe, these materials are characterized by low dispersion, the optical design is optimized for operation in a specific working band, and the AR-coating of each *πShaper* model is optimized for the respective spectrum, detailed specifications are given in Table 3.

Achromatic *πShaper* can be applied simultaneously with lasers of different wavelengths.

Table 3

πShaper 6_6 model	**AR-coating**	**Optimum* spectrum, nm**	**Working band, nm (acceptable performance)**	**Material of lenses**
7_7_10.6	V-type @10.6 µm	10000 - 11000	10000 - 11000	ZnSe
7_7_9.4	V-type @9.4 µm	9000 - 10000	9000 - 10000	ZnSe
7_7_5.1	V-type @5.3 µm	5000 - 5500	5000 - 5600	ZnSe
6_6_NIR	Broadband	1100 – 1700 achromatic	1050 – 1750	Optical glasses
6_6_VIS	Broadband	405 – 680 achromatic	400 – 700	Optical glasses
6_6_NUV	Broadband	335 – 560 achromatic	335 – 560	Optical glasses
6_6_1.9-2.8	Broadband	1900 - 2800	1700 - 3000	ZnSe
6_6_2.05	V-type @2 µm	1900 - 2160	1900 - 2200	Fused Silica
6_6_1550	V-type @1550 nm	1500 - 1600	1450 - 1650	Fused Silica
6_6_1064	V-type @1064 nm	1020 - 1100	980 - 1160	Fused Silica
6_6_TiS	V-type @800 nm	700 - 900	680 - 950	Fused Silica
6_6_532	V-type @532 nm	510 - 550	500 - 570	Fused Silica
6_6_350	V-type @350 nm	330 - 380	320 - 390	Fused Silica
6_6_325	V-type @325 nm	305 - 345	300 - 360	Fused Silica
6_6_266	V-type @266 nm	250 - 275	245 - 280	Fused Silica
6_6_213	V-type @213 nm	206 - 220	200 - 225	Fused Silica

Spectral transmission graphs for the popular *πShaper* models are presented in Fig. 5 (a) and (b).

These data are based on measurements of reflection of the optical surfaces with AR-coatings. Devices manufactured in various production batches may have deviations from the presented graphs.

When operating in the Optimum spectrum, the total losses do not exceed 6%.

The *πShaper* from fused silica, developed for use in relatively narrow spectral band, have V-type AR-coatings with minima at the design wavelengths, Table 1, are applied.

Achromatic *πShaper* from optical glasses have broadband AR-coatings.

Using *πShaper* at a wavelength outside the optimal spectral band will affect the increasing in loss.

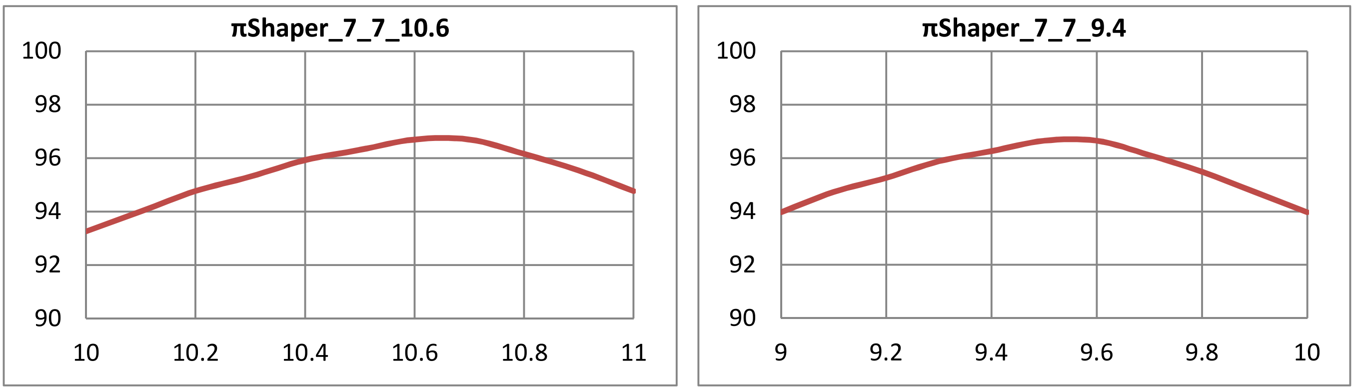


Figure 5 (a). *πShaper_7_7* Spectral transmission, %, versus wavelength, µm, other explanations in text.

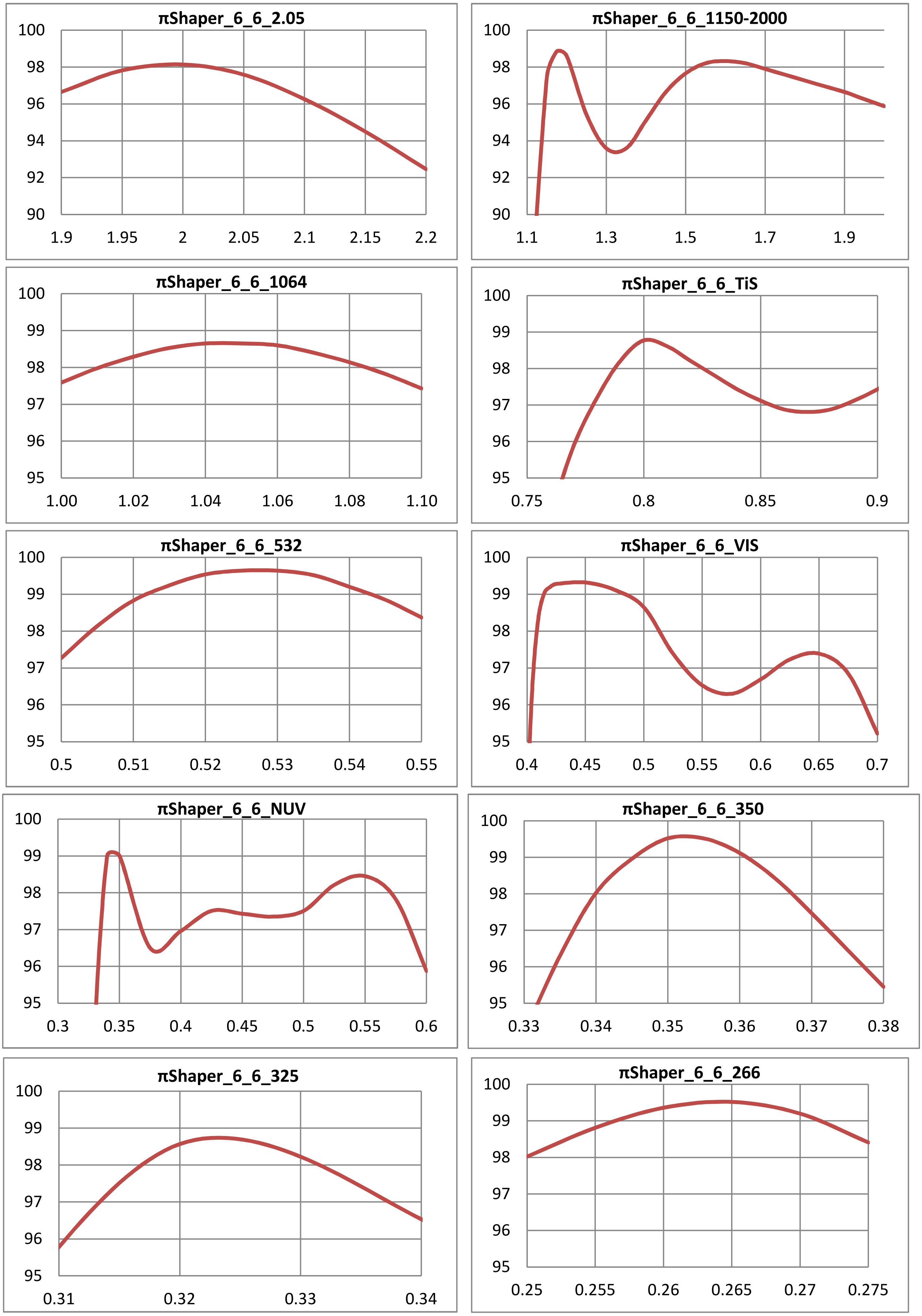


Figure 5 (b). *πShaper_6_6* Spectral transmission, %, versus wavelength, µm, other explanations in text.

6. *Features of Mechanical design*

General drawing of the *πShaper* implementation with overall dimensions is presented in Fig. 6.

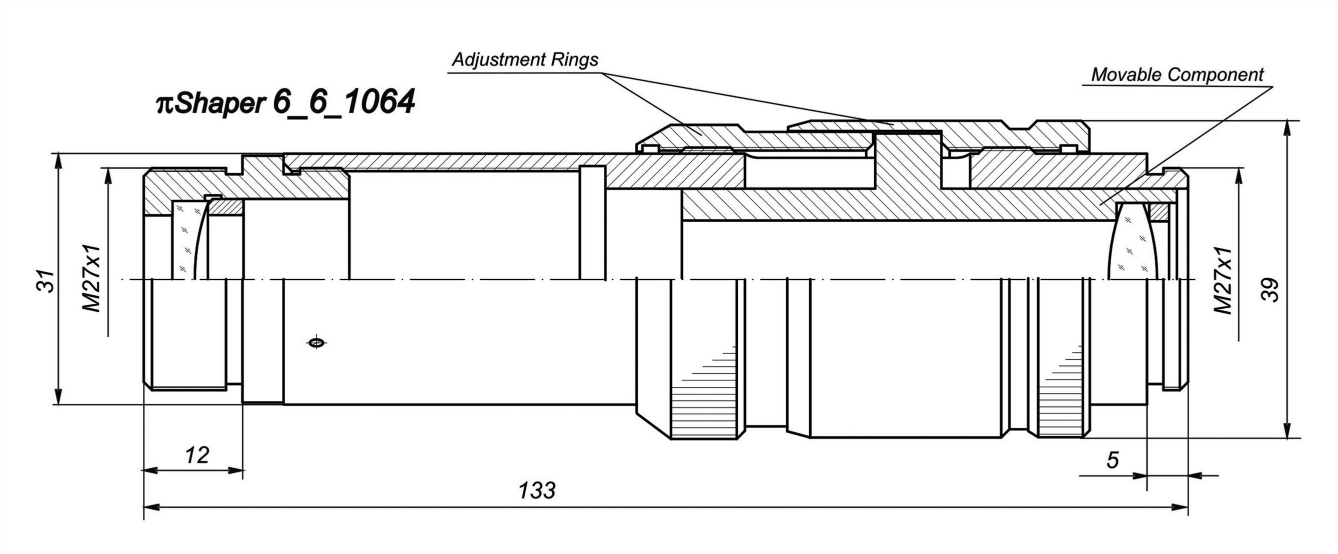


Figure 6. Basic mechanical designs of the *πShaper*.

Mounting. All *πShaper* models have the same mounting design: **M27x1** mounting thread at both ends of the *πShaper***.**

It is assumed that the *πShaper* is mounted in the optical system by means of these threads, preferably using the 4-axis Mounts described in the next Chapter.

Other mounting methods should be discussed with the Supplier.

Movable Component. One of the *πShaper* components, on the output side, is movable. This feature is provided to adapt the beam shaper to actual conditions of operation, such as the working wavelength, the divergence/convergence of the input beam.

*Note: Movement of the πShaper Component is the **last** step in the adjustment procedures;*
it should only be done, when the 4-axis alignment has been completed !

The movement in the range of ±10 mm (±5 mm in obsolete versions) is provided by rotating the Adjustment Rings, Figs. 3 and 6:

- step-by-step rotating the two Adjustment Rings,
- these Rings are used also for fixation of the movable component.

The adjustment rings are always located closer to the exit.

The criterion of the proper adjustment is the collimated output beam, i.e. providing the beam of lowest divergence.

*Note: Movement of the πShaper Component is the **last** step in the adjustment procedures;*
it should only be done, when the 4-axis alignment has been completed !

The *πShaper* is equipped with a Scale of 1 mm pitch, which is used to determine the position of the movable component. Original position of components with respect to each other is optimized for the design wavelength, Table 1.

Thus, the general suggestion when working with *πShaper* is as follows:

- start from the original position and
- perform the 4-axis alignment procedure, see the next Chapter and the recommendations presented in

  http://www.adloptica.com/manual/Alignment_pish66_f_pish9.pdf
  http://youtu.be/hinngpo4knY
  http://pishaper.com/pdfs/alignment.zip?Align=Download+Alignment+video,

  and provide a symmetric output beam,
- turn the Adjustment Ring(s) to compensate for the divergence or convergence of the input laser beam and to achieve a collimated output beam, i.e. the beam with the lowest divergence.

*Note: Movement of the πShaper Component is the **last** step in the adjustment procedures;*
it should only be done, when the 4-axis alignment has been completed !

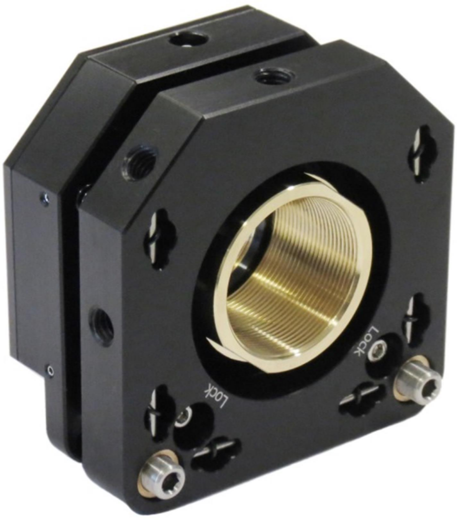
Note: Moving the output component is provided for correction purposes only!
In terms of divergence, compensation is provided for a maximum range of ±4 mrad !

7. *Alignment*

The *πShaper* is an optical device with a narrow field of view; therefore it is sensitive to errors of its positioning relative to the input beam. The results of theoretical calculations characterizing the sensitivity of *πShaper* to displacements and tilts, as well as experimental examples, are described below in the Appendix in a separate chapter "Behavior of ***πShaper_6_6_1064*** when misalignments" . To ensure the correct result of beam profile conversion, it is necessary to take care of the *πShaper* alignment in the optical system; the adjustments should be

- lateral translations along the X/Y axes, i.e. perpendicular to the optical axis, and
- tilts around the X/ Y axes.

The optomechanical design of the complete optical system with *πShaper* must contain a 4-axis mount for its alignment; examples of such tools are presented in Fig.7 and 8.



Tilt/tip	range	±4°
	sensitivity	3arcsec
X/Y translation	range	±2 mm
	sensitivity	1 µm
Thread for the πShaper mounting		M27x1 internal
Mounting Holes		Thread M6, 6 positions
Overall dimensions		66 x 66 x 34 mm
Weight		320 g

Figure 7. Mount M27, 4-axis, for the πShaper mounting, ***lockable***

The lockable 4-axis Mount M27, Fig. 7, provides firm alignment and fixation of the *πShaper*, it is recommended for use in industrial equipment, as well as in other applications where stable positioning of the optics is required. Examples of mounting the *πShaper* using the Mount M27 with a demonstration of design features are presented in Fig. 9.

Detailed design information about the Mount M27 is presented in http://pishaper.com/shaper_adjust.html#tabs-1

The 4-axis Mount presented in Fig. 8 is not equipped with locks; however, it has the knurled screws, which makes it very convenient for use in laboratory conditions or for quick setup of the πShaper for test purposes, see also

http://pishaper.com/shaper_adjust.html#tabs-2

Tilt/tip	ange	±2°
	sensitivity	3 arcsec
X/Y translation	range	±2 mm
	sensitivity	1 µm
Thread for the πShaper mounting		M27x1 internal
Mounting Hole		Thread M6, 2 positions
Overall dimensions		77 x 77 x 65 mm
Weight		200 g

Figure 8. 4-axis Mount, without locking, for laboratory use.

Figure 9. The *πShaper* mounted in the Mount M27:

(a) side view,
(b) the screws of the tilt around the X/Y axes, as well as the locking screws are shown,
(c) the screws of the X/Y latreral translation mechanism and locking screws are shown.

The *uniform intensity* distribution and the *symmetric view* of the beam at the *πShaper* output are the criteria for proper alignment.

Note: To evaluate the intensity distribution, it is strongly recommended to use dedicated instruments, for example, camera-based beam profilers!
Do not use the Scanning Slit beam profilers!

Tolerances for the *πShaper 6_6* and *πShaper 7_7* alignment:

- lateral displacement ±0,1 mm;
- angular tilt ±0,1°.

Examples of the beam profile transformation under the conditions of the correct *πShaper* alignment are presented in Figs.2 and 12.

Recommendations to alignment procedure are presented in

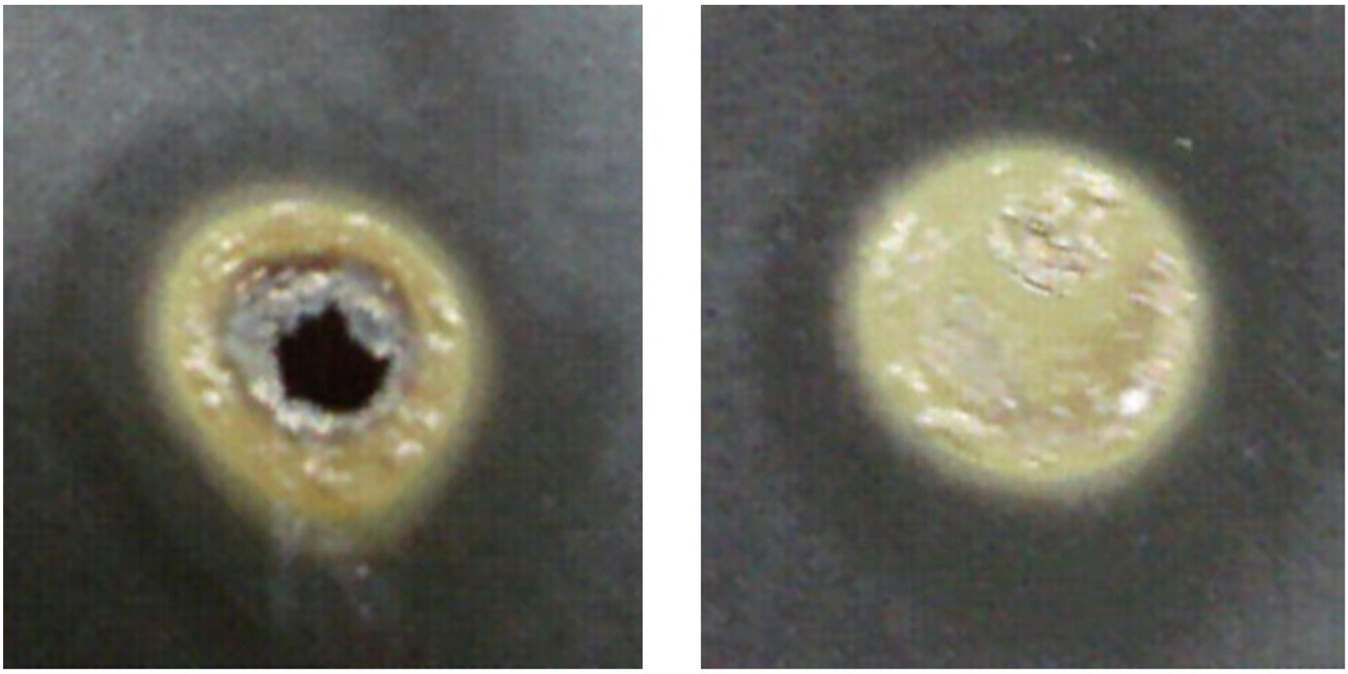
http://www.adloptica.com/manual/Alignment_pish66_f_pish9.pdf

http://youtu.be/hinngpo4knY

http://pishaper.com/pdfs/alignment.zip?Align=Download+Alignment+video

8. *Example of the πShaper_6_6_1064 operation*

An illustration of the *πShaper* influence on the results of material processing with using the laser is presented at left picture. Here one can see a comparison of engraving of a depression in a material with pure TEM_{OO} laser as well as with the same laser but with a *πShaper* after it.



a) Direct engraving by TEM_{00} laser **b) Engraving by TEM_{00} laser with πShaper**

Figure 10. Examples of material processing (a) without and (b) with a *πShaper* (*Courtesy of EO Technics*).

Difference is evident - irregular shape of the depression with a ragged unwished hole in the middle in case of direct engraving with the TEM_{00} laser, good shaped round depression with a controlled depth when applying the *πShaper*.

9. *Data for communication with a supplier*

By the communication with a supplier for evaluation of the optics alignment and performance, it is recommended to present, beforehand, the following data measured using a ***camera-based*** beam profiler:

- Input beam
    - profile at the entrance of the *πShaper*, with numerical data for the $1/e^2$ diameter,
    - divergence, numerical data, for example by measuring $1/e^2$ beam diameter from the laser source at distances 50 mm, 500 mm, 1000 mm, 2000 mm,
    - astigmatism and ellipticity, numerical data,
- Output beam profile at the exit of the *πShaper* at distances 20 mm, 100 mm, 500 mm,

Do not use the Scanning Slit beam profilers!

as well as

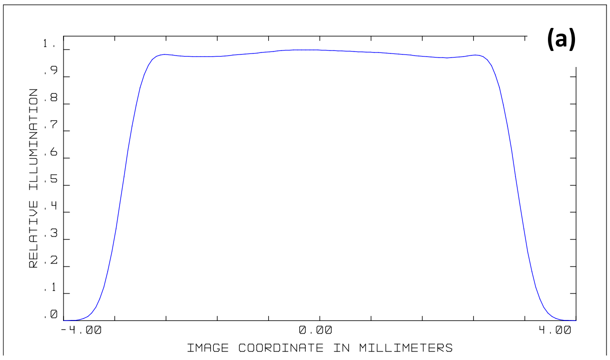
- Setting of the Adjustment ring,
- Serial number of the unit, engraved on the housing,
- Main specifications of the laser:
    - wavelength,
    - CW or pulse,
    - M^2,
    - power specifications,
    - pulse energy,
    - pulse width?

Data with material processing are considered **ONLY** when the above mentioned measured profiles are presented.

10. *Appendix*

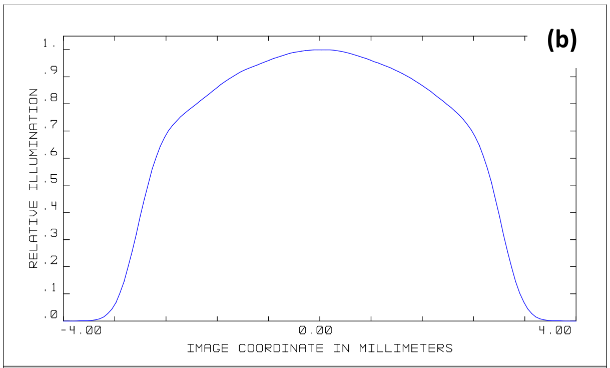
<u>*πShaper* 6_6_VIS</u>

<u>Variation in the output intensity profile with a variation of the diameter of the TEM_{00} Gaussian input beam</u>

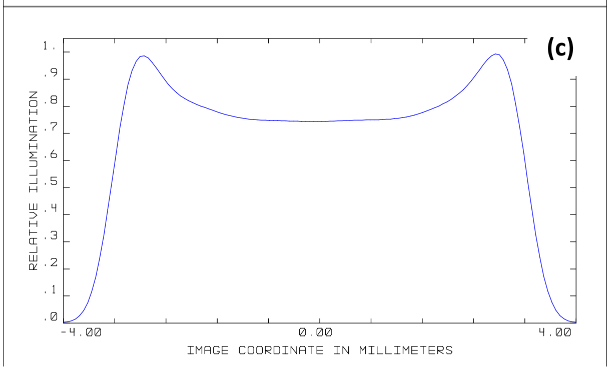


Input $1/e^2$ diameter **<u>6 mm</u>**.
According to design the non-uniformity of the output beam intensity distribution is within ±2% range.

Variation of diameter of source laser beam



Input $1/e^2$ diameter **<u>5 mm</u>**.



Input $1/e^2$ diameter **<u>7 mm</u>**.

Figure 11. Output profiles by variable $1/e^2$ diameter of input Gaussian beam.

The feature of the field mapping beam shapers that *output beam profile depends on the input beam size*, Fig. 11, can be used as a powerful and convenient tool to vary the resulting intensity distribution by simple changing of laser beam diameter with using an ordinary zoom beam expander ahead of the ***πShaper***.

This approach is demonstrated in Fig. 11 where results of theoretical calculations as well as measured in real experiments beam profiles for TEM_{00} laser are shown. The data relate to the ***πShaper 6_6*** which design presumes that a perfect Gaussian beam with $1/e^2$ diameter 6 mm to be converted to a beam with uniform intensity (flattop) with FWHM diameter 6.2 mm. When the input beam has a proper size the resulting beam profile is flattop, Fig.11(a). Increasing of input beam diameter leads to downing of intensity in the centre, Fig.11(c), sometimes this distribution is called as "inverse-Gauss"; input beam size reduction allows getting a convex profile that approximately can be described by super-Gauss functions, Fig.11(b).

An interesting feature of the field mapping beam shapers is in stability of the output beam size – variation of input beam diameter results in variation of intensity profile while the output beam diameter stays almost invariable. This is very important in practice and brings element of stability while searching for optimum conditions for a particular laser application.

Experimental data of operation of ***πShaper 6_6_1064*** are presented in Fig. 12, next page.

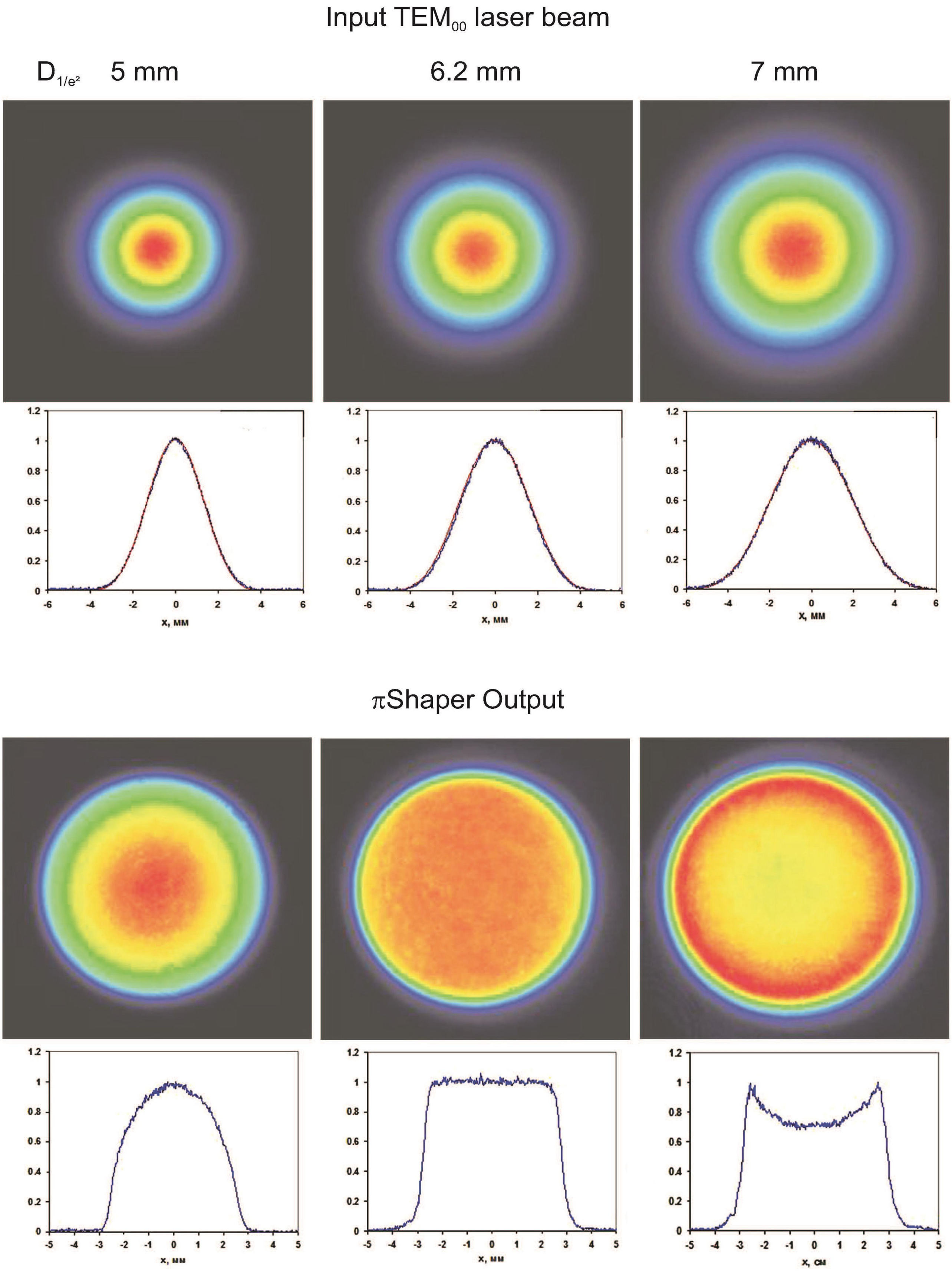


Figure 12. *πShaper* operation by variable diameter of perfect Gaussian input beam.

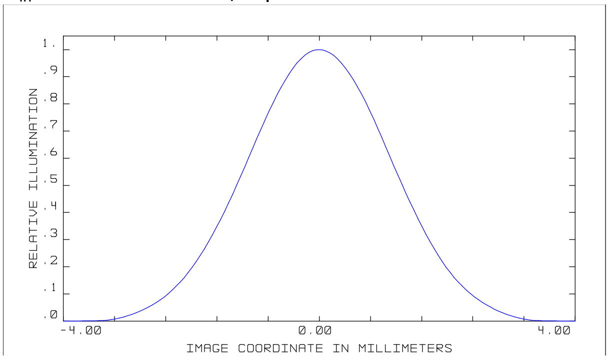
πShaper 6_6_VIS
Providing a flat-top output profile with input beams which profiles deviate from the Gaussian function

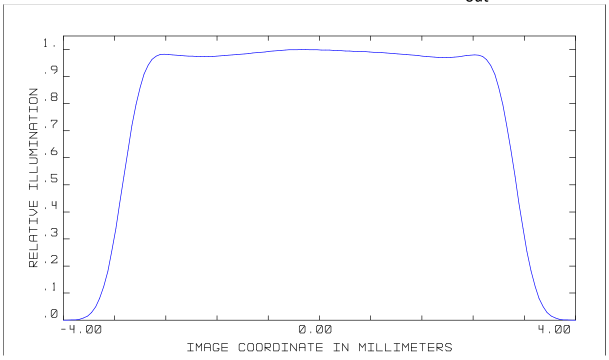
Left Column – data for input beam:

- Diameter D_{in} for $1/e^2$ intensity level,
- Gaussian Apodisation of Factor=1 corresponds to TEM_{00} beam of M^2=1,
- Diameter is adjusted to get uniform intensity profile at output of ***πShaper***.

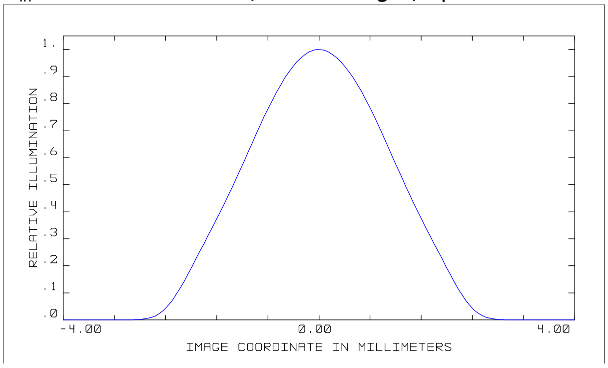
Right Column –data for output beam profile and D_{out} diameter at the Full Width at Half Maximum (FWHM) Intensity.

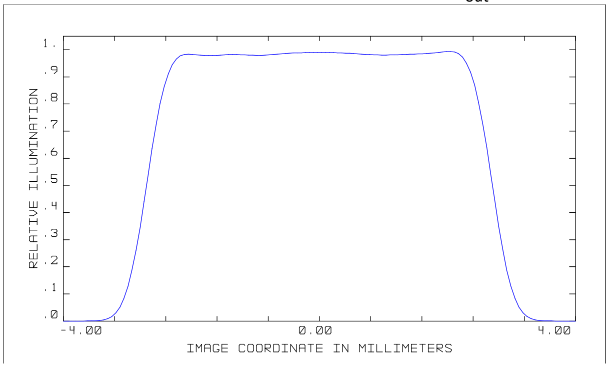
D_{in} = 6 mm *Gaussian*, Apodisation Factor 1 | D_{out} = 6.0 mm



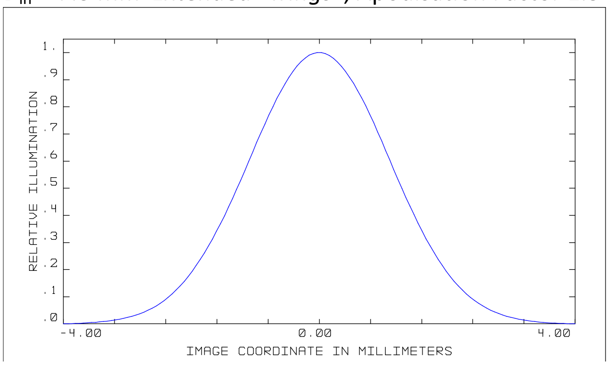


D_{in} = 4.4 mm *Parabolic, short "wings"*, Apodisation Factor 0.5 | D_{out} = 5.4 mm





D_{in} = 7.3 mm *Extended "wings"*, Apodisation Factor 1.5 | D_{out} =6.4 mm



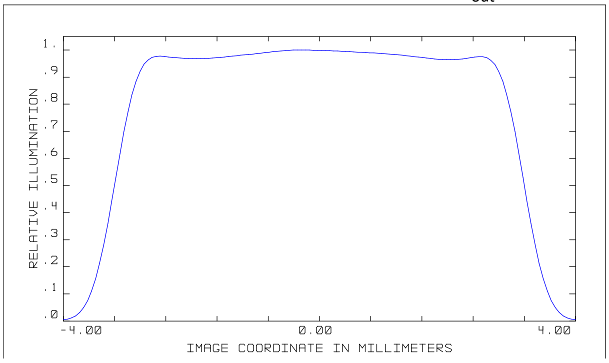


Figure 13. ***πShaper*** operation by variable profile (intensity distribution) of input beam.

Apodisation Type

By default, the pupil is always illuminated uniformly. However, there are times when the pupil should have a non-uniform illumination. For this purpose, ZEMAX supports pupil Apodisation, which is a variation of amplitude over the pupil. Three types of pupil Apodisation are supported: uniform, Gaussian, and tangential. Uniform means rays are distributed uniformly over the entrance pupil, simulating uniform illumination. Gaussian Apodisation imparts an amplitude variation over the pupil that is Gaussian in form. The Apodisation factor refers to the rate of decrease of the beam amplitude as a function of radial pupil coordinate. The beam amplitude is normalized to unity at the center of the pupil. The amplitude at other points in the entrance pupil is given by

$$A(\rho) = \exp(-G\rho^2),$$

where G is the Apodisation factor and ρ is the normalized pupil coordinate. If the Apodisation factor is zero, then the pupil illumination is uniform. If the Apodisation factor is 1.0, then the beam amplitude has fallen to the 1 over e point at the edge of the entrance pupil (which means the intensity has fallen to the 1 over e squared point, about 13% of the peak). The Apodisation factor can be any number greater than or equal to 0.0.

<u>Behavior of *πShaper 6_6_1064* when misalignments</u>

Correct alignment is important for any beam shaping optics; let's evaluate the effect of misalignments in the case of the refractive field mapping beam shapers. Fig. 14 presents results of mathematical simulation, as well as measurements of real profiles for the *πShaper 6_6* in three cases: perfectly aligned, lateral beam displacement, angular tilt of the beam shaper.

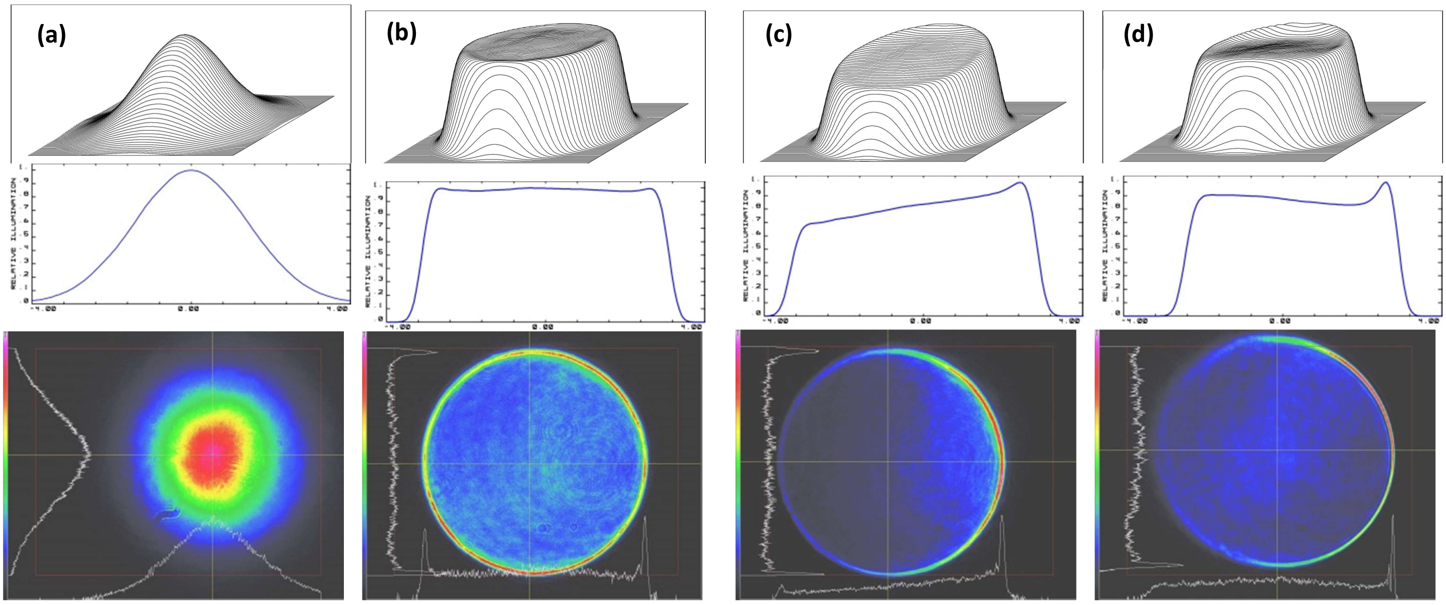


Figure 14 To the evaluation of the sensitivity of misalignments, theoretical and experimental intensity profiles for ***πShaper 6_6_1064*** @ 1064nm: a) Input TEM_{00} beam, b) Output by perfect alignment c) Output by lateral shift at 0.5 mm, d) Output by tilt at 1^o.

The aberration correction of *πShaper* systems is provided for the clear aperture (CA) diameter of at least 1.6 times larger than the $1/e^2$ diameter of a laser beam. Therefore, a small, up to ±20% of the diameter, lateral displacement of the beam with respect to the beam shaper or vice versa doesn't lead to aberration, but allows obtaining an interesting beam shaping effect – the output profile is skewed in direction of the lateral displacement, this is shown in Fig. 14 (c). The intensity profile itself remains flat, but tilts in the direction of the displacement; and a remarkable feature is that the beam itself remains collimated and low divergent. This inclined profile can be used in applications where a steady increase or decrease of intensity is required, for example, to compensate for the attenuation of an acoustic wave in acousto-optical devices.

As an optical system designed to work with axial beams, *πShaper* operates in a relatively narrow angular field; the data in Fig. 14 (d) demonstrate the behaviour of the intensity profile when the beam shaper is tilted at 1^o. The intensity profile remains stable, but there is noticeable deterioration in quality on the left and right sides of the spot due to aberrations, first of all coma. It should be noted that the tilt of 1^o means for the considered *πShaper 6_6* the lateral displacement of one of its ends by about 2 mm! No doubts, this displacement can be easily compensated by conventional opto-mechanical mounts, for example by the 4-axis Mounts described in the Chapter 7.

These data show that misalignments affect the *πShaper* operation, but the sensitivity to these misalignments is not high: even with significant lateral displacement (up to 0,5 mm!) and tilt (up to 1^o!) the resulting profiles are close to flat-top. In other words, the tolerance of positioning of a beam shaper is rather not tough, and misalignments can be compensated by conventional opto-mechanical 4-axis mounts. Since the influence of a tilt on the wave aberration of the output beam is quite pronounced, it is recommended to pay more attention to the angular alignment when setting up the beam shapers.

πShaper 6_6 performance is practically unchanged with angular tilt misalignments of up to ± 0.1 ° or lateral displacements of up to ± 0.1 mm.