Technical Description and Application Examples

FBS Top Hat Beam Shaper

1. FBS – Top-Hat Beam Shaper

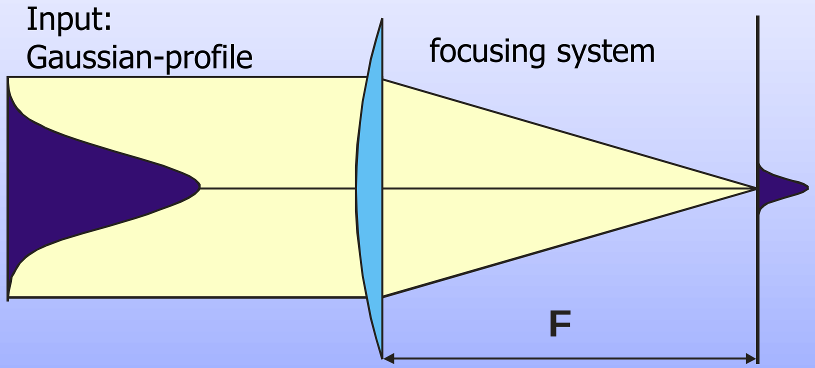
Diffractive Beam Shaping Concept based on Fourier methods;

FBS -> **F**undamental **B**eam Mode **S**haper

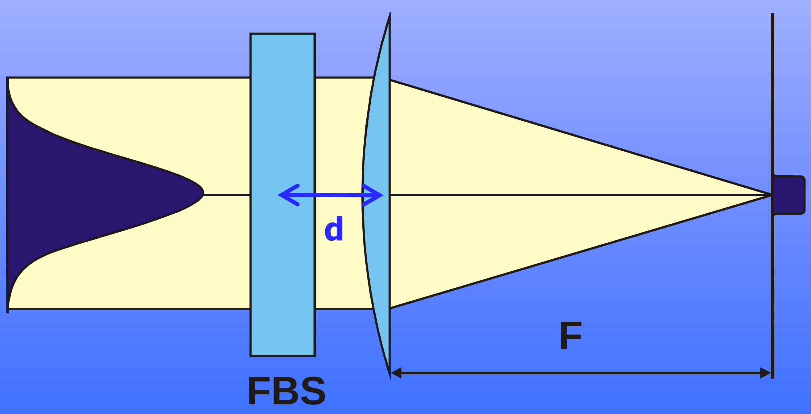
Transforming Gaussian TEM_{00} beam into square or round homogeneous Top-Hat profile;

Top Hat size is near diffraction limit and is given by: ~λ /NA;

Achievable Top Hat sizes: **1µm – 200µm**



without FBS Beam Shaper: Gaussian-profile at focal plane

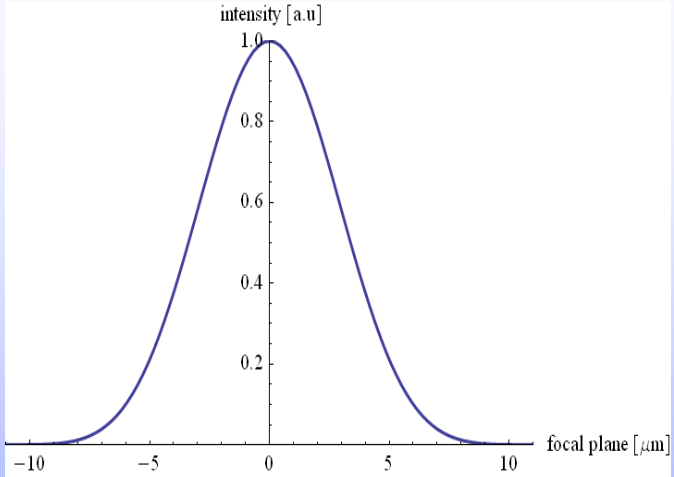


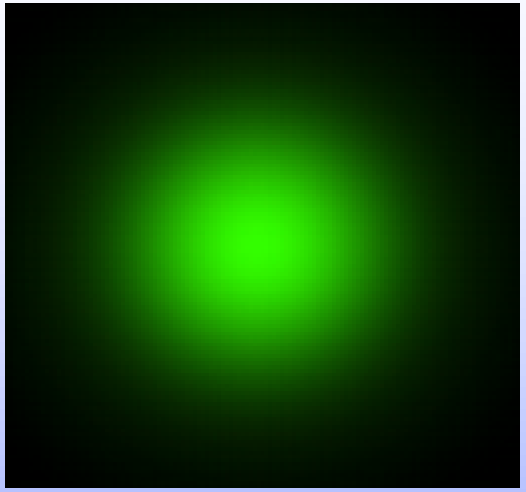
with FBS Beam Shaper: Top-Hat-profile at focal plane

- FBS works together with focusing system (FS)
- Top Hat size just depends on wavelength (λ) and numerical aperture (NA) of focused beam
- distance d between FBS and FS up to several meters

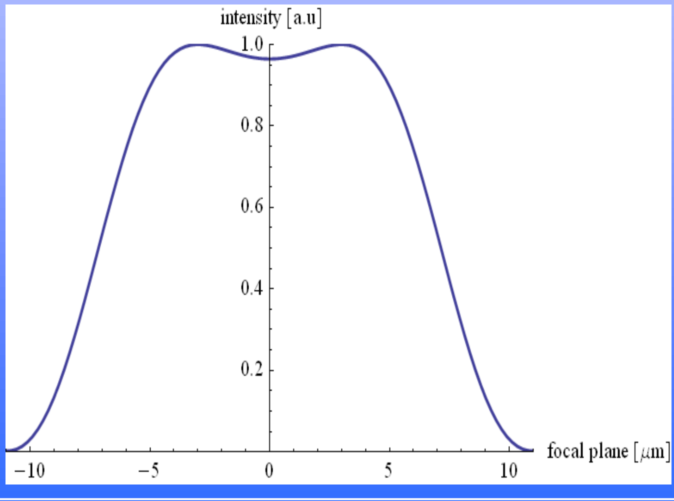
2. Intensity distribution at focal plane
- without and with FBS Top Hat beam shaper -

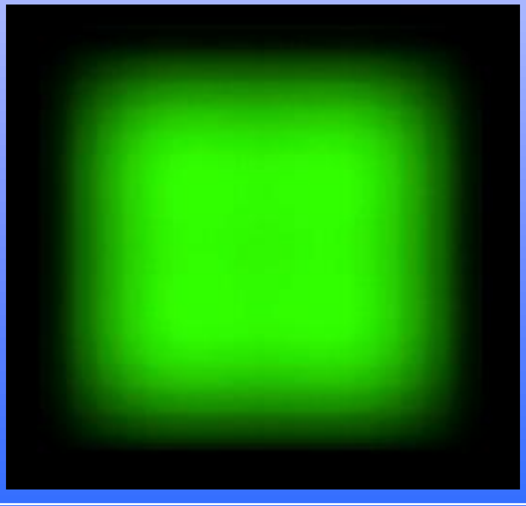
- without FBS shaper ⇨ diffraction limited Gaussian profile





- with FBS shaper ⇨ near diffraction limit Top Hat profile





Main FBS advantages:

- smallest achievable Top-Hat size: ≈ always 1,5x of diffraction limited Gaussian-spot @ $1/e^2$
- achievable Top Hat profiles: square
- diffraction efficiency: > 95% of energy in Top Hat
- homogeneity: modulation < (+/-) 2,5%
- insensitive to misalignment, ellipticity and input diameter variation: (+/-) 5-10%

3. Optical setup for FBS Top-Hat beam shaper
- setup overview -

There are different possibilities to integrate the FBS beam shaper into an optical setup:

a. Beam shaper directly in front of a focusing optic/objective

b. Beam shaper in front of a beam expander

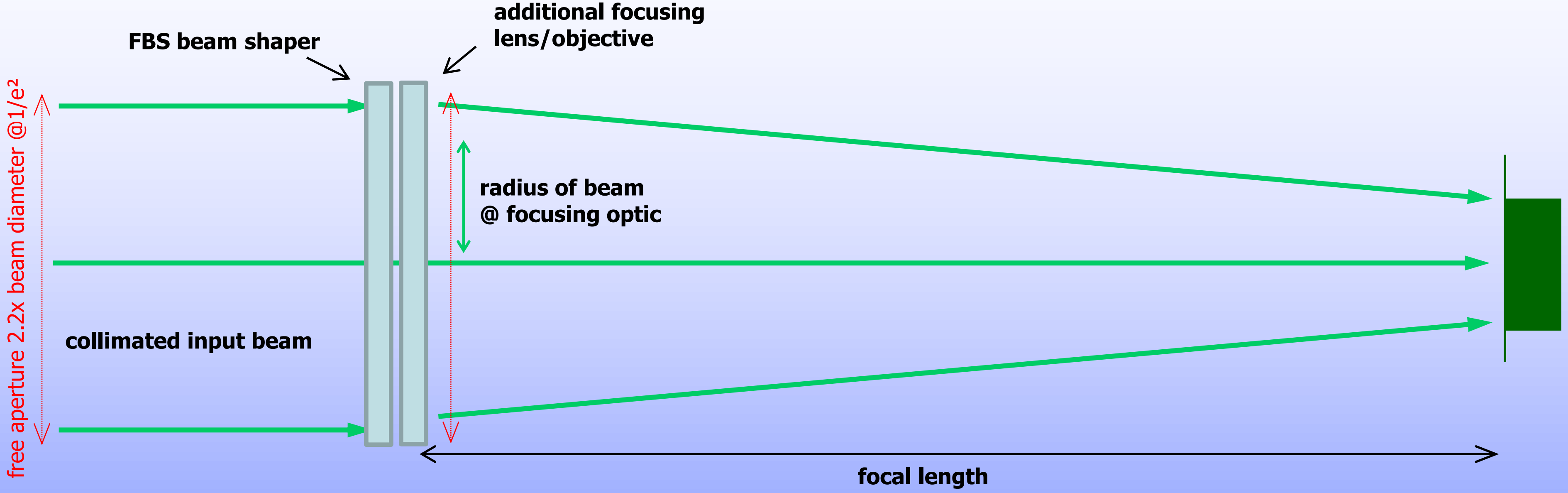
c. Beam shaper within a beam expander

Independent of optical setup the user has to consider that:

- The free aperture along the total beam path have to be at least 2.2x (better 2.5x) bigger than the beam diameter @ $1/e^2$

- The Top Hat size is always given by: $\frac{\lambda}{NA}$
  λ is the used wavelength;
  NA is the numerical aperture of focused beam and is given by: $\frac{\text{beam radius @ focusing optic}}{\text{focal length of focusing optic}}$

3a. Optical setup for FBS Top-Hat beam shaper
- beam shaper in front of focusing optic -

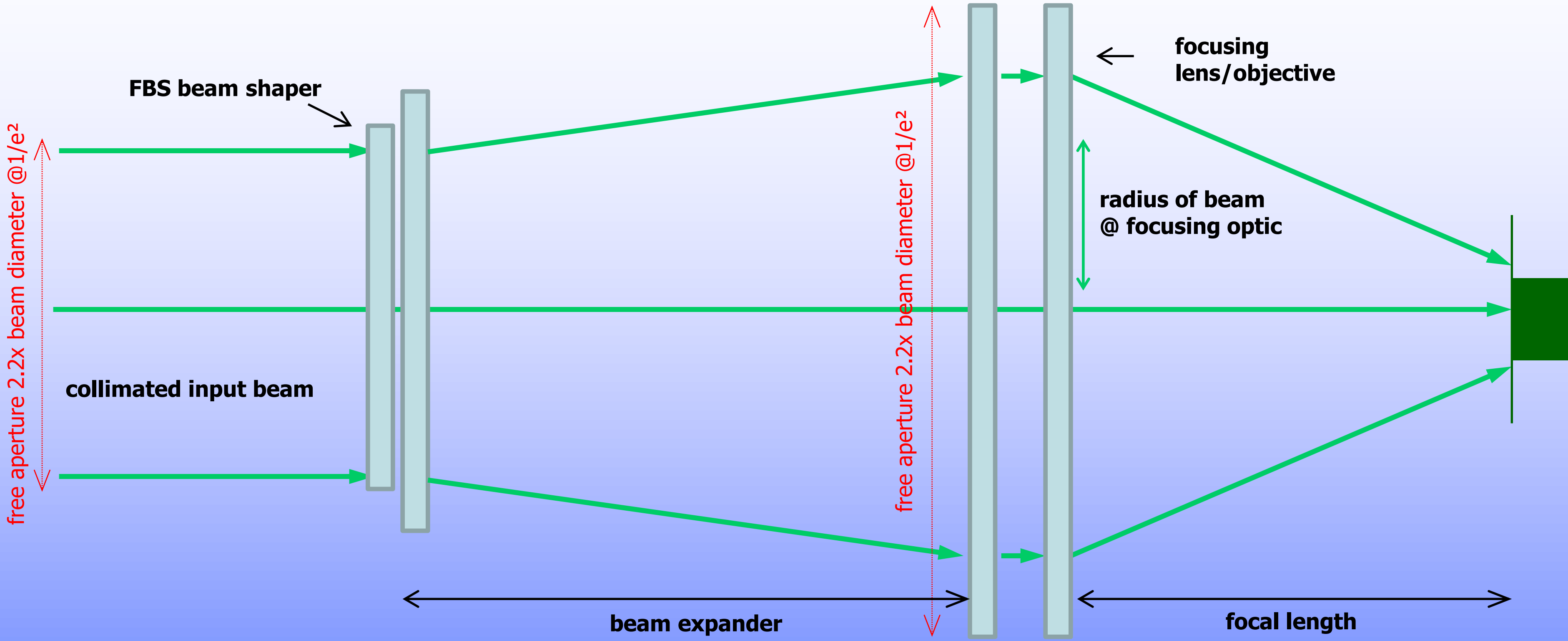


By introducing the FBS beam shaper into the beam path in front of a lens/objective the initial diffraction limited Gaussian spot will be transformed into a homogeneous Top-Hat profile.

When a Gaussian TEM_{00} input beam with a diameter of 5mm@1/e² is used the diameter of the free aperture along the total beam path have to be at least 11mm (better 13mm).

If for example a wavelength with 532nm, a Gaussian TEM_{00} input beam with a diameter of 5mm@1/e² and a focusing lens with f=160mm is used, ones will get a homogeneous Top Hat profile with a diameter of 34µm.

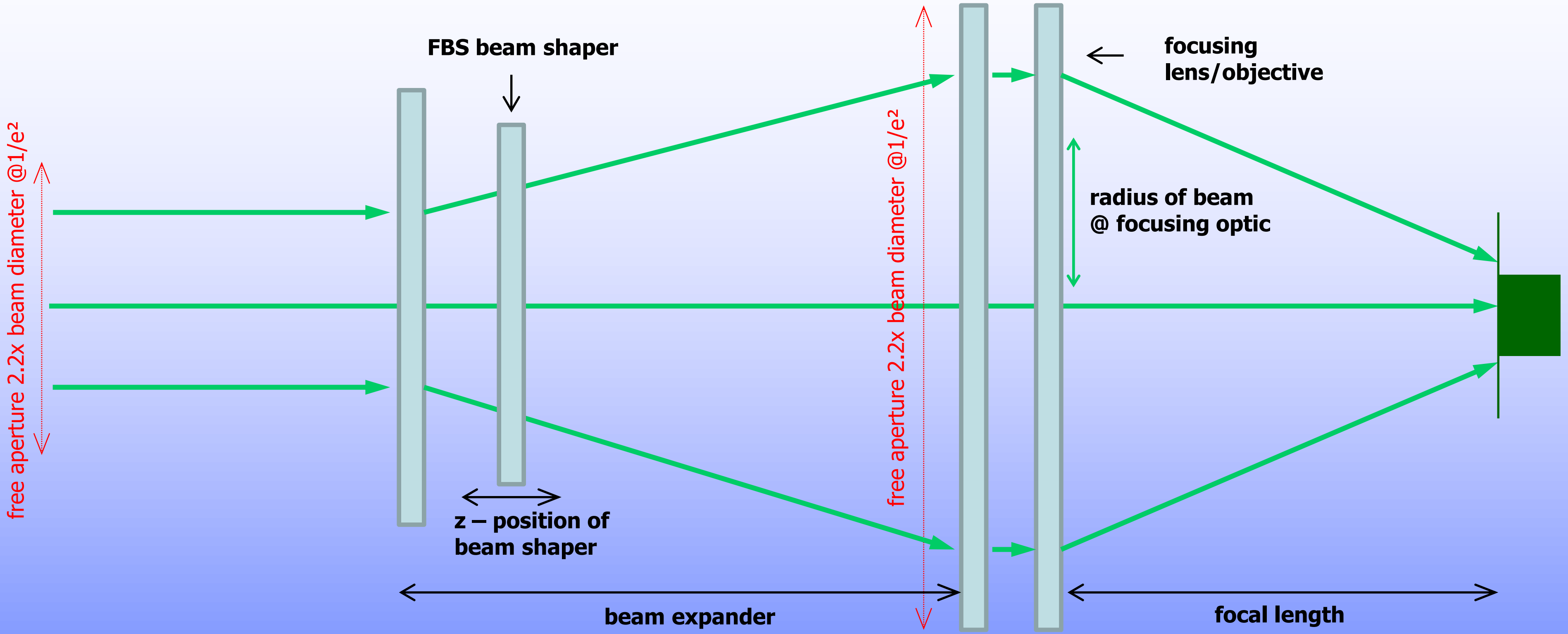
3b. Optical setup for FBS Top-Hat beam shaper
- beam shaper in front of beam expander -



There is also the possibility to introduce the FBS beam shaper into the beam path in front of a beam expander. This leads to a higher numerical aperture of focused beam and to a smaller Top Hat profile.

Example: A Gaussian beam with a diameter of 5mm@$1/e^2$ illuminates the FBS beam shaper and is afterwards increased by a beam expander to a beam diameter of 8mm. With an focusing optic with f=50mm the user can generate a Top Hat with a diameter of 7µm. The needed free aperture increases with the expanded beam. For a beam with a diameter of 8mm the free aperture have to be at least 18mm.

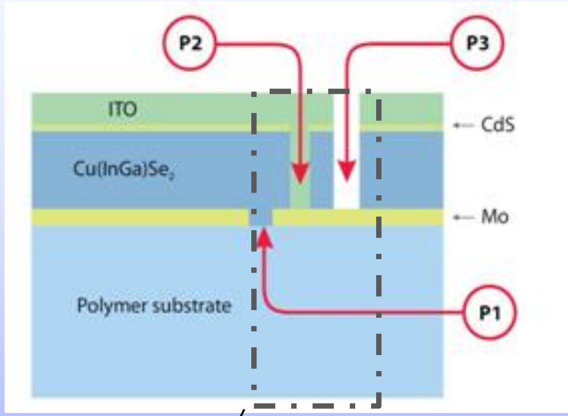
3c. Optical setup for FBS Top-Hat beam shaper
- beam shaper within beam expander -



A further and even more flexible possibility is to introduce the FBS beam shaper into the beam path within a beam expander. The user has the possibility for an easy "fine tuning" of beam diameter at the position of FBS beam shaper by shifting the shaper along z-axis.

4.FBS-Beam Shaping: for Photovoltaics

Scribing of CIGS-solar cells

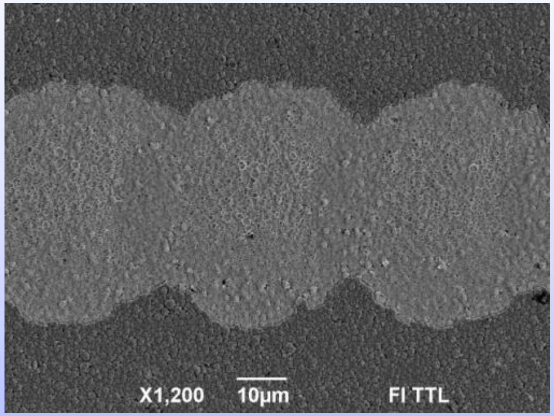


wasted area, reducing efficiency
-> need of smallest scribing lines

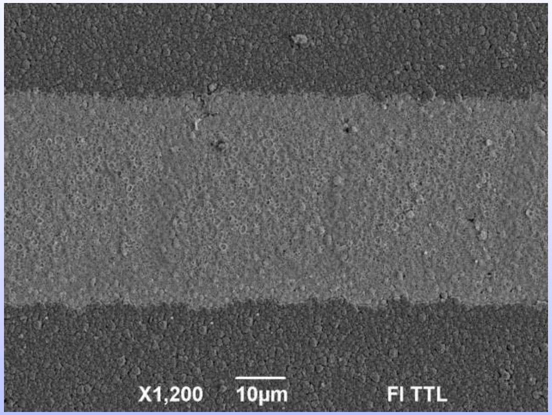
Cut quality influence efficiency
-> need of small HAZ, no debris,
smooth edges

high scanning speed for high throughput
- > need of small pulse overlap

P1-„Scribing“



Gaussian Profile



FBS-Top-Hat Profile

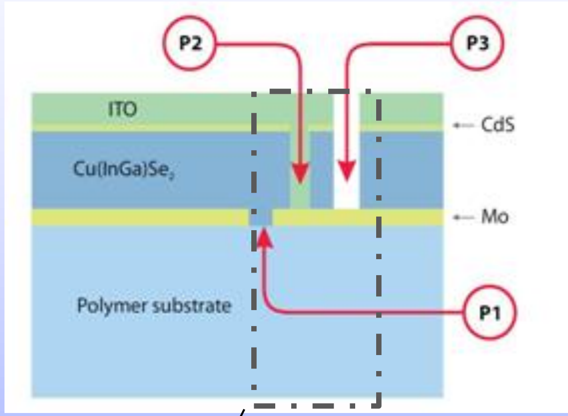
-> small overlap, smooth edges

Removal of a front contact in ZnO(1µm)/CIGS/Mo/PI structure.
Laser PL10100/SH, 10ps, 370mW, 100kHz, 532nm; scanning speed 4.3 m/s, single pass.

Raciukaitis et. al, JLMN-Vol. 6, No. 1, 2011

4.FBS-Beam Shaping: for Photovoltaics

Scribing of CIGS-solar cells

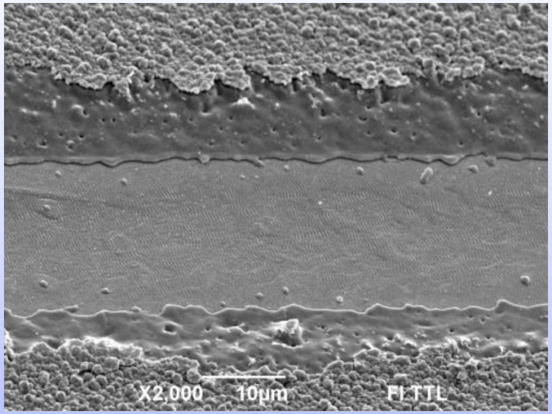


wasted area, reducing efficiency
-> need of smallest scribing lines

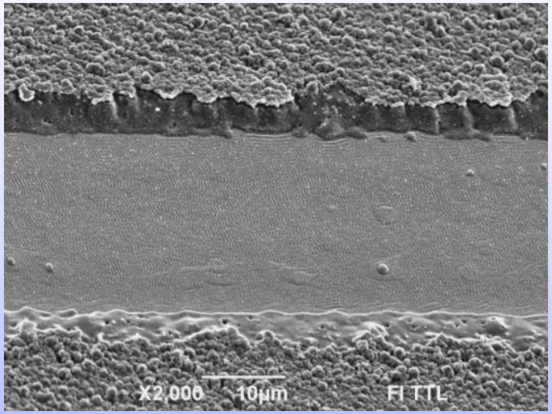
Cut quality influence efficiency
-> need of small HAZ, no debris,
smooth edges

high scanning speed for high throughput
- > need of small pulse overlap

P3-„Scribing"



Gaussian Profile



FBS-Top-Hat Profile

-> small HAZ, smooth edges

Tilted SEM pictures of the P3 scribe in ZnO(1µm)/CIGS/ Mo/PI structure.
Laser PL10100/SH, 10ps, 370mW, 100kHz, 532 nm; scanning speed 60 mm/s, single pass.

Raciukaitis et. al, JLMN-Vol. 6, No. 1, 2011

Specifications of FBS Top Hat beam shaper

material:	fused silica	
diameter:	25.4 mm	tolerance +/- 0.1 mm
input beam:	TEM_{00}, different models for diameter@1/e²: 2.0, 3.0 … or 10 mm	tolerance +/- 5 %
necessary free aperture:	2.2x (or better 2.5x) beam diameter@1/e²	along total beam path
Top Hat size:	1,5x diffraction limited Gaussian spot	square form (round optional)
homogenity:	+/- 2.5%	rel. to average intensity within tophat
wavelength:	different models for: 1064nm, 532nm or 355nm	others on request
transmission:	> 99%	AR/AR coating
efficiency:	> 95 %	of input energy within tophat profile
damage threshhold:	4 J/cm² @ 532nm, 10 ns	
recommendation:	x/y-adjustment mount HSF02	free aperture: 23 mm
accessories:	beam expander	