VIRMOS

MASK MANUFACTURING UNIT

Optimization of the cutting parameters
Slit edge quality reference measurements

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EVOLUTION PAGE

Issue	Rev.	Paragr.	Date	Observations
1	0		20/03/00	Optimization and reference measurements
1	1	3.2	10/04/00	Change of filter on the slit profile

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1.INTRODUCTION

This document is issued on the eve of the MMU PAE and gives

- the outcome of the optimization of the laser cutting parameters
- the resulting slit edge quality obtained with the optimized parameters.

2.OPTIMIZATION OF THE CUTTING PARAMETERS

During the past months, several combinations of the cutting parameters have been tested with the aim of obtaining the combination which could give the best quality of the slit edge.

This work was preceded by a fine tuning of the LPKF Stencillaser mechanics, like distance between the nozzle and the invar sheet, planarity of the invar sheet once fixed on the XY stage, centering of the laser beam with respect to the nozzle, replacement of the felt ring with a *teflon* one in order to avoid the possibility of felt particles depositing on the slits.

The final outcome of this optimization procedure has established that the best slit cutting parameters are the following:

1. Laser power: 16 W (regulation on)
2. Voltage: 231 V
3. Frequency of the pulsed beam: 1200 Hz
4. Beam pulse length: 0.19 msec
5. Cutting speed: 6 mm/sec
6. Beam diameter: 0.04 mm

This setting has been defined as the *cutting fine tool* which is always used to cut the slits. The mask contours are cut by another tool, the main difference being that the cutting speed is increased to 20 mm/sec.

3.ROUGHNESS OF THE SLIT EDGES

3.1SAMPLE CUTTING

A standard series of samples is a set of 9 (3 rows of 3) squares distributed in the whole mask area. The sample squares have dimensions 30x30 mm.

3.2ROUGHNESS MEASUREMENT

As a sample square is cut, it is immediately placed in the roughness meter for evaluation of the edge profile characteristics. The measurement is carried out by means of a calibrated knife probe exploring the whole thickness of one of the edges along a length of 25.4 mm.

The analysis software, after removing the linear trend due to the possible inclination of the sample in the vice of the measuring device, can provide two sets of parameters on which to evaluate the quality of the profile :

1. Parameters denoted by *R* evaluate the roughness at frequencies higher than a cutoff given by the filter width used to analyze the profile ;
2. Parameters denoted by *W* evaluate the roughness at frequencies lower than a cutoff given by the filter width used to analyze the profile : these parameters are properly called waviness parameters.

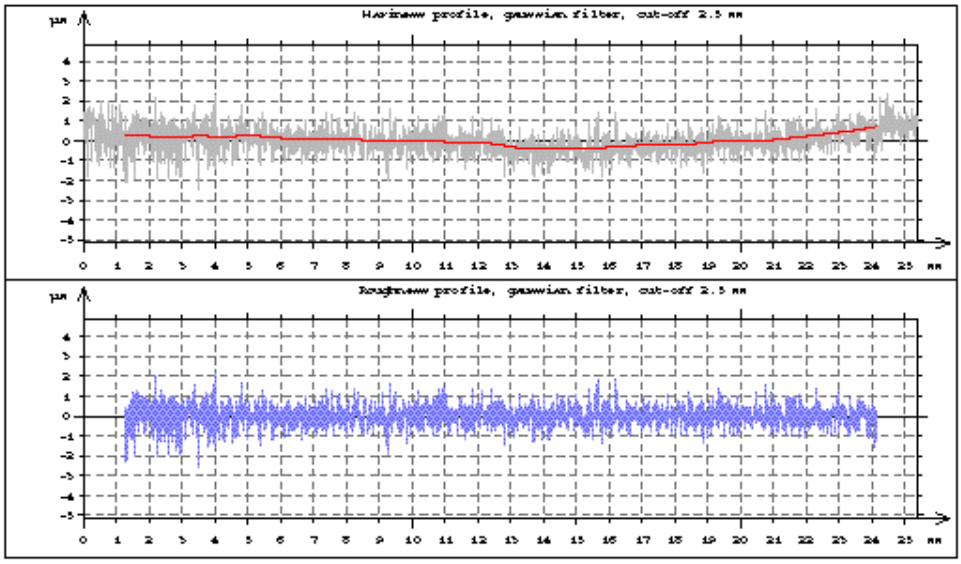
All parameters, with the exception of Wt, Rt, WPC and RPC, which are relevant to the total length, are averages of the values computed individually on each sampling length, where one sampling length is equal to the filter cutoff.

In the following figures, the raw levelled profile is shown in grey, the waviness profile (giving the roughness on scale equal or larger than the filter cutoff) is shown in red, and the roughness profile (giving the roughness at scales smaller than the filter cutoff) is shown in blue.

We have selected two cutoffs to characterize the scales significant for VIRMOS : 2.5 mm and 0.12 mm. The full analysis, carried out on sample no. 7, the third worst in the reference samples), is illustrated in Figures 1 (page 6) and 2 (page 7).

Figure 1 (page 6) shows the waviness and roughness profiles obtained with a gaussian filter of HWHM 2.5 mm, thus corresponding to about half the length of a typical slit. The waviness profile gives the shape of the cut, and its deviation from a straight cut. The roughness profile shows all structures below the filter cutoff, and it is not particularly meaningful.

Figure 2 (page 7) shows the waviness and roughness profiles obtained with a gaussian filter of HWHM 0.12 mm, thus corresponding to the pixel size in the focal plane. The waviness profile gives the actual roughness at or above the pixel scale : its parameters are those better matching the roughness specifications. The associated roughness profile shows all structures below the filter cutoff, and thus allows to evaluate the residual microroughness at the sub-pixel level.



Parameters calculated on the profile 1200Hz24 > Levelled

* Parameters calculated by mean of all the sampling lengthes.
* A microroughness filtering is used, with a ratio of 2.5 µm.

Roughness parameters, Gaussian filter, 2.5 mm

Ra	= 0.393 µm	Arithmetic Mean Deviation of the assessed (roughness) Profile
Rq	= 0.491 µm	Root-Mean-Square (RMS) Deviation of the assessed (roughness) Profile
Rp	= 1.62 µm	Maximum (roughness) Profile Peak Height
Rv	= 1.54 µm	Maximum (roughness) Profile Valley Depth
Rz	= 3.16 µm	Maximum Height of (roughness) Profile
Rt	= 4.75 µm	Total Height of (roughness) Profile
RPC	= 0 pks/cm (+/- 2.5 µm)	Peak Count on the (roughness) Profile

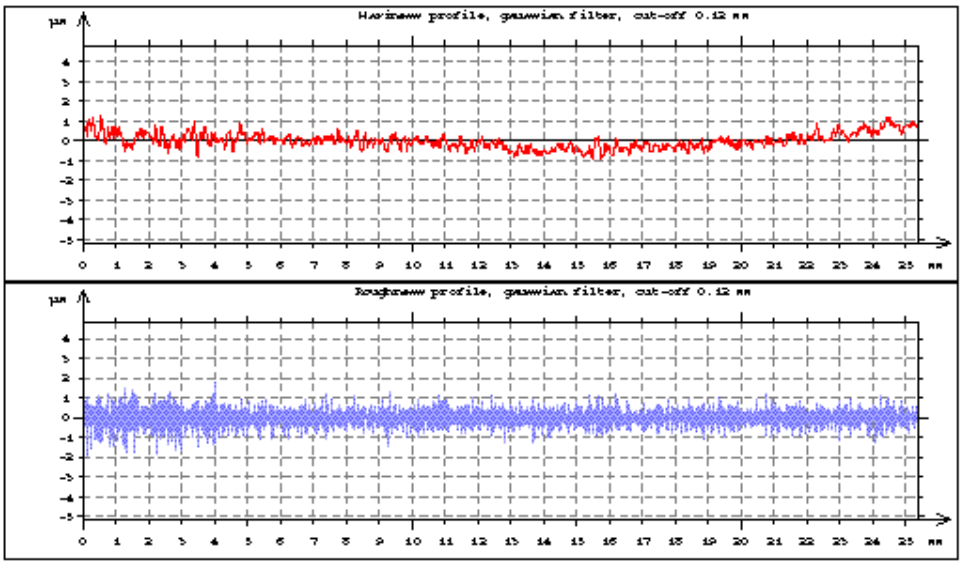
Waviness parameters, Gaussian filter, 2.5 mm

Wa	= 0.192 µm	Arithmetic Mean Deviation of the assessed (waviness) Profile
Wq	= 0.204 µm	Root-Mean-Square (RMS) Deviation of the assessed (waviness) Profile
Wz	= 0.2 µm	Maximum Height of (waviness) Profile
Wt	= 1.13 µm	Total Height of (waviness) Profile
WPC	= 0 pks/cm (+/- 0.5 µm)	Peak Count on the (waviness) Profile

Identity card

Name: 1200Hz24 > Levelled
Created on: 00/02/10 11:41:30

Axis: X
Length: 25.4 mm
Size: 3907 points
Spacing: 6.5 µm
Axis: Z
Length: 4.75 µm
Size: 297 digits
Spacing: 16 nm



Parameters calculated on the profile 1200Hz24 > Levelled

* Parameters calculated by mean of all the sampling lengthes.
* A microroughness filtering is used, with a ratio of 2.5 µm.

Roughness parameters, Gaussian filter, 0.12 mm

Ra	= 0.282 µm	Arithmetic Mean Deviation of the assessed (roughness) Profile
Rq	= 0.369 µm	Root-Mean-Square (RMS) Deviation of the assessed (roughness) Profile
Rp	= 0.667 µm	Maximum (roughness) Profile Peak Height
Rv	= 0.735 µm	Maximum (roughness) Profile Valley Depth
Rz	= 1.4 µm	Maximum Height of (roughness) Profile
Rt	= 3.67 µm	Total Height of (roughness) Profile
RPC	= 0 pks/cm (+/- 2.5 µm)	Peak Count on the (roughness) Profile

Waviness parameters, Gaussian filter, 0.12 mm

Wa	= 0.268 µm	Arithmetic Mean Deviation of the assessed (waviness) Profile
Wq	= 0.337 µm	Root-Mean-Square (RMS) Deviation of the assessed (waviness) Profile
Wz	= 0.43 µm	Maximum Height of (waviness) Profile
Wt	= 2.29 µm	Total Height of (waviness) Profile
WPC	= 0 pks/cm (+/- 2.5 µm)	Peak Count on the (waviness) Profile

Tables 1, 2 and 3, and the roughness measurement reference atlas give the following parameters, measured for each of the 9 samples, which we believe are the best suited to evaluate the slit edge quality :

- *On a scale representative of the slit length (2.5 mm) :*
  - *Wt*, total height of the (waviness) profile
- *On the scale of the pixel size (0.12 mm) :*
  - *Wq*, the rms deviation of the assessed (waviness) profile,
  - *Wz*, the maximum height of the (waviness) profile,
  - *Wt*, the total height of the the (waviness) profile,
  - *WPC*, the peak count on the (waviness) profile, measured in peaks/cm above a threshold of ±2.5 μm,
  - *Rq*, the rms deviation of the assessed (roughness) profile,
  - *Rz*, the maximum height of the (roughness) profile,
  - *Rt*, the total height of the (roughness) profile,
  - *RPC*, the peak count on the (roughness) profile, measured in peaks/cm above a threshold of ±2.5 μm,

Table 1 : Profile shape, filter width 2.5 mm

Sample no.	Wt (μm)
1	1.660
2	0.703
3	0.480
4	0.826
5	0.754
6	0.460
7	1.130
8	0.511
9	0.499
Mean	**0.780**
std	**0.395**

Table 2 : Profile roughness, filter width 0.12 mm

Sample no.	Wq (μm)	Wz (μm)	Wt (μm)	WPC (no./cm)
1	0.502	0.507	4.01	0
2	0.255	0.405	1.91	0
3	0.245	0.444	2.27	0
4	0.322	0.496	2.23	0
5	0.339	0.634	8.50	0
6	0.267	0.461	2.00	0
7	0.337	0.430	2.29	0
8	0.268	0.480	1.94	0
9	0.238	0.431	2.11	0
Mean	**0.308**	**0.476**	**3.03**	**0**

std	**0.083**	**0.068**	**2.15**	**0**

Table 3 : Profile microroughness, filter width 0.12 mm

Sample no.	Rq (μm)	Rz (μm)	Rt (μm)	RPC (no./cm)
1	0.376	1.44	5.37	0
2	0.347	1.32	3.46	0
3	0.421	1.62	3.77	0
4	0.431	1.65	4.58	0
5	0.479	1.82	12.00	0.791
6	0.417	1.59	3.99	0
7	0.369	1.40	3.67	0
8	0.419	1.57	4.10	0
9	0.374	1.42	4.12	0
Mean	**0.404**	**1.54**	**5.01**	**0.088**
std	**0.041**	**0.16**	**2.68**	**0.264**

This set of measurements can be taken as a reference to check the quality of the cut during the Stencillaser lifetime.

3.3ROUGHNESS MEASUREMENT CONDITIONS

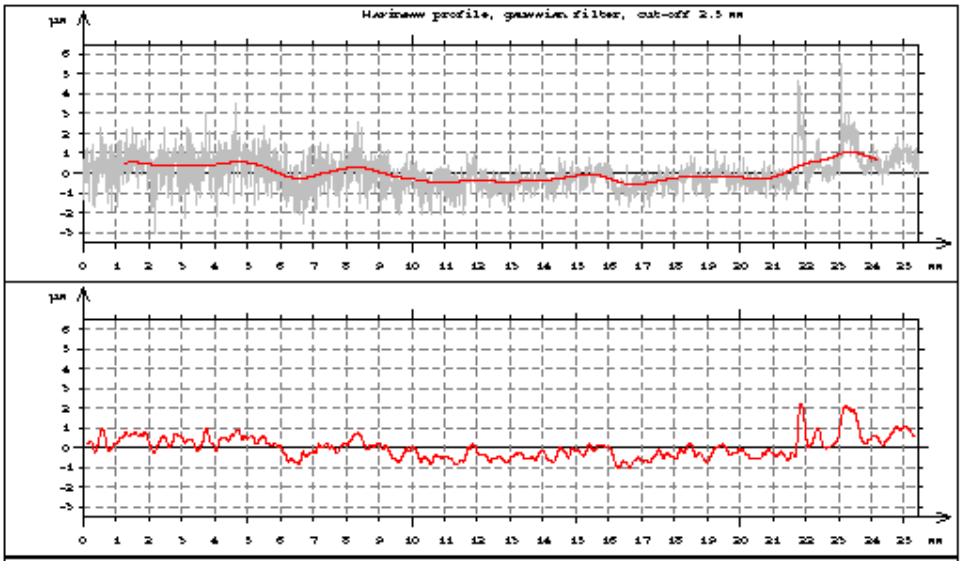
It has been our experience that roughness measurements at the micron level are very sensitive to the environment conditions and manipulation of the samples to be measured.

When samples are left around for some time, especially in a normal environment, dust will deposit on them resulting in higher values of most of the parameters. Manipulation of the samples can also modify the real values. Thus, the procedure we adopted foresees the measurement of only one side of the sample squares (the others will get in touch with the roughness meter parts) carried out immediately after the sample is extracted from the machine to avoid dust deposition.

Some of these precautions might be superfluous in Paranal, where the room will be air conditioned and will have double doors towards the outside.

4.ATLAS OF THE SAMPLE PROFILES

The following figures show the profiles measured on the reference samples.



Parameters calculated on the profile 1200Hz0 > Levelled

Profile shape on slit size scale

Waviness parameters, Gaussian filter, 2.5 mm

Wt = 1.66 µm
Total Height of (waviness) Profile

Profile roughness on pixel si:

Waviness parameters, Gaussian filter, 0.12 mm

Wq = 0.502 µm
Root-Mean-Square (RMS) Deviation of the assessed (waviness) Profile
Wz = 0.507 µm
Maximum Height of (waviness) Profile
Wt = 4.01 µm
Total Height of (waviness) Profile
WPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (waviness) Profile

sub-pixel microroughn

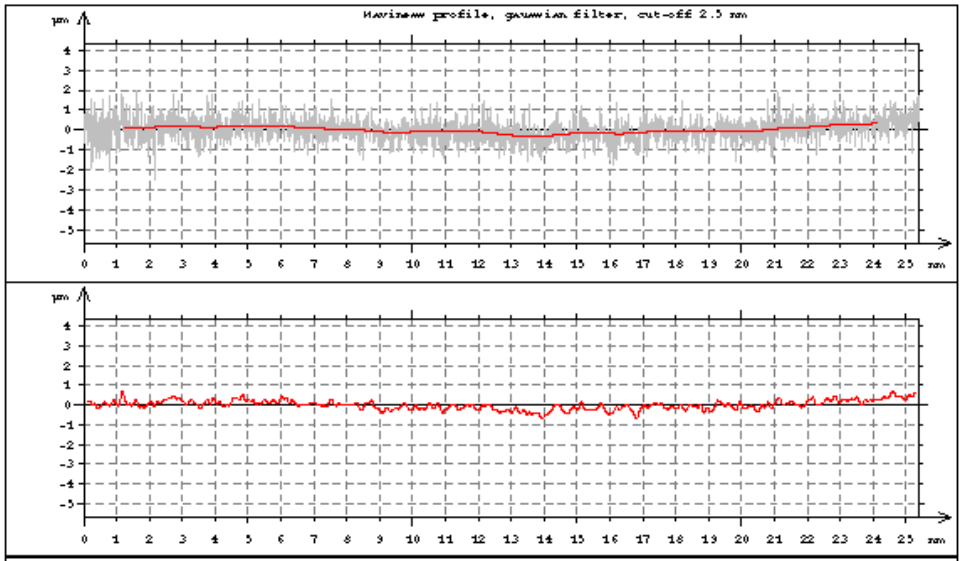
Roughness parameters, Gaussian filter, 0.12 mm

Rq = 0.376 µm
Root-Mean-Square (RMS) Deviation of the assessed (roughness) Profile
Rz = 1.44 µm
Maximum Height of (roughness) Profile
Rt = 5.37 µm
Total Height of (roughness) Profile
RPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (roughness) Profile

Identity card

Name: 1200Hz0 > Levelled
Created on: 00/02/10 11:18:18

Axis: X
Length: 25.4 mm
Size: 3907 points
Spacing: 6.51 µm
Axis: Z
Length: 8.46 µm
Size: 529 digits
Spacing: 16 nm



Parameters calculated on the profile 1200Hz4 > Levelled

Profile shape on slit size scale

Waviness parameters, Gaussian filter, 2.5 mm

Wt = 0.703 µm
Total Height of (waviness) Profile

Profile roughness on pixel si:

Waviness parameters, Gaussian filter, 0.12 mm

Wq = 0.255 µm
Root-Mean-Square (RMS) Deviation of the assessed (waviness) Profile
Wz = 0.405 µm
Maximum Height of (waviness) Profile
Wt = 1.91 µm
Total Height of (waviness) Profile
WPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (waviness) Profile

sub-pixel microroughn

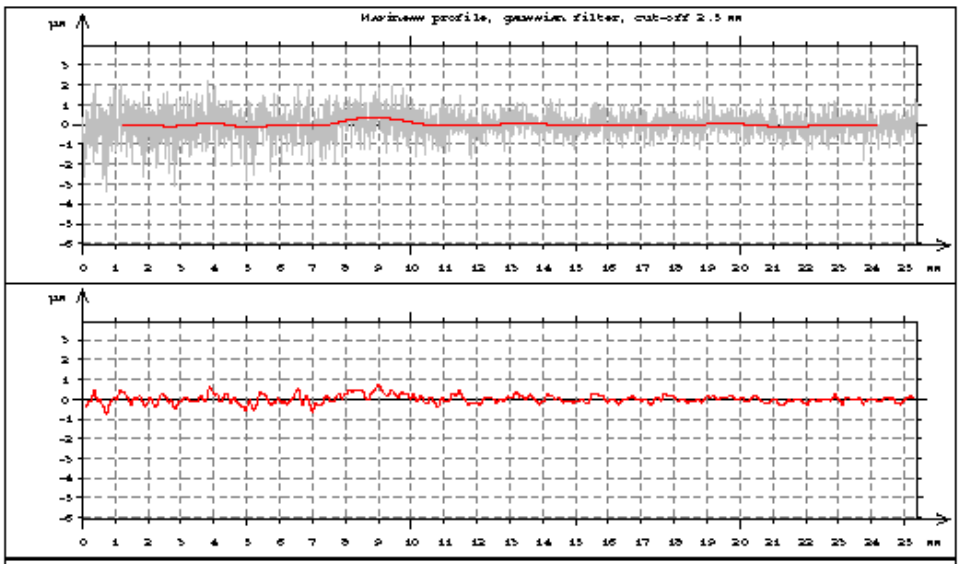
Roughness parameters, Gaussian filter, 0.12 mm

Rq = 0.347 µm
Root-Mean-Square (RMS) Deviation of the assessed (roughness) Profile
Rz = 1.32 µm
Maximum Height of (roughness) Profile
Rt = 3.46 µm
Total Height of (roughness) Profile
RPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (roughness) Profile

Identity card

Name: 1200Hz4 > Levelled
Created on: 00/02/10 11:23:26

Axis: X
Length: 25.4 mm
Size: 3907 points
Spacing: 6.5 µm
Axis: Z
Length: 4.45 µm
Size: 278 digits
Spacing: 16 nm



Parameters calculated on the profile 1200Hz8 > Levelled

Profile shape on slit size scale

Waviness parameters, Gaussian filter, 2.5 mm

Wt = 0.48 µm
Total Height of (Waviness) Profile

Profile roughness on pixel si

Waviness parameters, Gaussian filter, 0.12 mm

Wq = 0.245 µm
Root-Mean-Square (RMS) Deviation of the assessed (Waviness) Profile
Wz = 0.444 µm
Maximum Height of (Waviness) Profile
Wt = 2.27 µm
Total Height of (Waviness) Profile
WPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (Waviness) Profile

sub-pixel microroughn

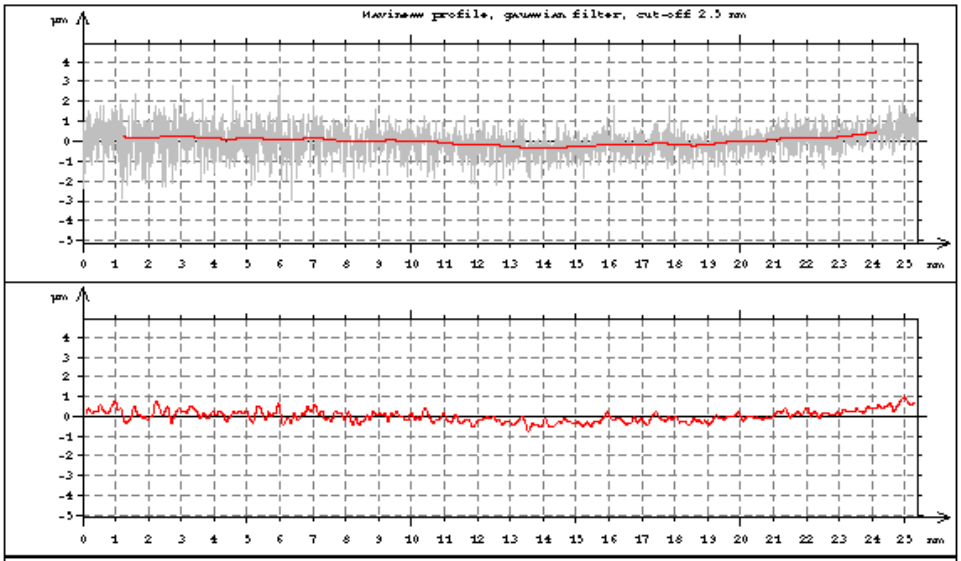
Roughness parameters, Gaussian filter, 0.12 mm

Rq = 0.421 µm
Root-Mean-Square (RMS) Deviation of the assessed (roughness) Profile
Rz = 1.62 µm
Maximum Height of (roughness) Profile
Rt = 3.77 µm
Total Height of (roughness) Profile
RPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (roughness) Profile

Identity card

Name: 1200Hz8 > Levelled
Created on: 00/02/10 11:27:07

Axis: X
Length: 25.4 mm
Size: 3907 points
Spacing: 6.5 µm
Axis: Z
Length: 5.6 µm
Size: 350 digits
Spacing: 16 nm



Parameters calculated on the profile 1200Hz12 > Levelled

Profile shape on slit size scale

Waviness parameters, Gaussian filter, 2.5 mm

Wt = 0.826 µm
Total Height of (waviness) Profile

Profile roughness on pixel si:

Waviness parameters, Gaussian filter, 0.12 mm

Wq = 0.322 µm
Root-Mean-Square (RMS) Deviation of the assessed (waviness) Profile
Wz = 0.496 µm
Maximum Height of (waviness) Profile
Wt = 2.23 µm
Total Height of (waviness) Profile
WPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (waviness) Profile

sub-pixel microroughn

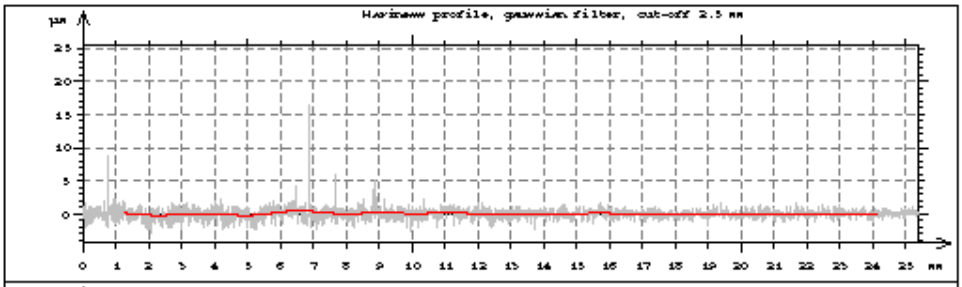
Roughness parameters, Gaussian filter, 0.12 mm

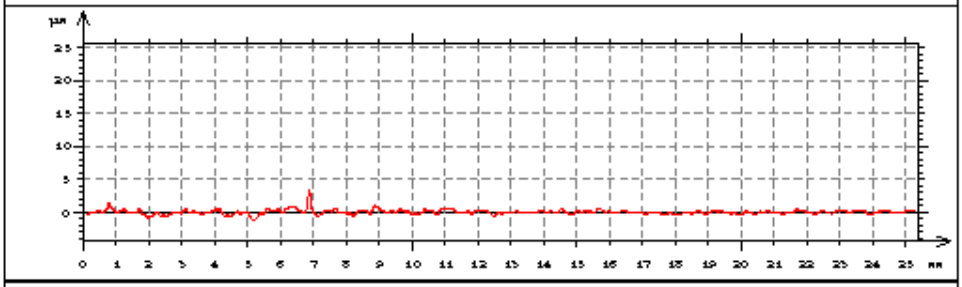
Rq = 0.431 µm
Root-Mean-Square (RMS) Deviation of the assessed (roughness) Profile
Rz = 1.65 µm
Maximum Height of (roughness) Profile
Rt = 4.58 µm
Total Height of (roughness) Profile
RPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (roughness) Profile

Identity card

Name: 1200Hz12 > Levelled
Created on: 00/02/10 11:30:21

Axis: X
Length: 25.4 mm
Size: 3907 points
Spacing: 6.5 µm
Axis: Z
Length: 5.76 µm
Size: 360 digits
Spacing: 16 nm





Parameters calculated on the profile 1200Hz16 > Levelled

Profile shape on slit size scale

Waviness parameters, Gaussian filter, 2.5 mm

Wt = 0.754 µm
Total Height of (Waviness) Profile

Profile roughness on pixel si:

Waviness parameters, Gaussian filter, 0.12 mm

Wq = 0.339 µm
Root-Mean-Square (RMS) Deviation of the assessed (Waviness) Profile
Wz = 0.634 µm
Maximum Height of (Waviness) Profile
Wt = 8.5 µm
Total Height of (Waviness) Profile
WPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (Waviness) Profile

sub-pixel microroughn

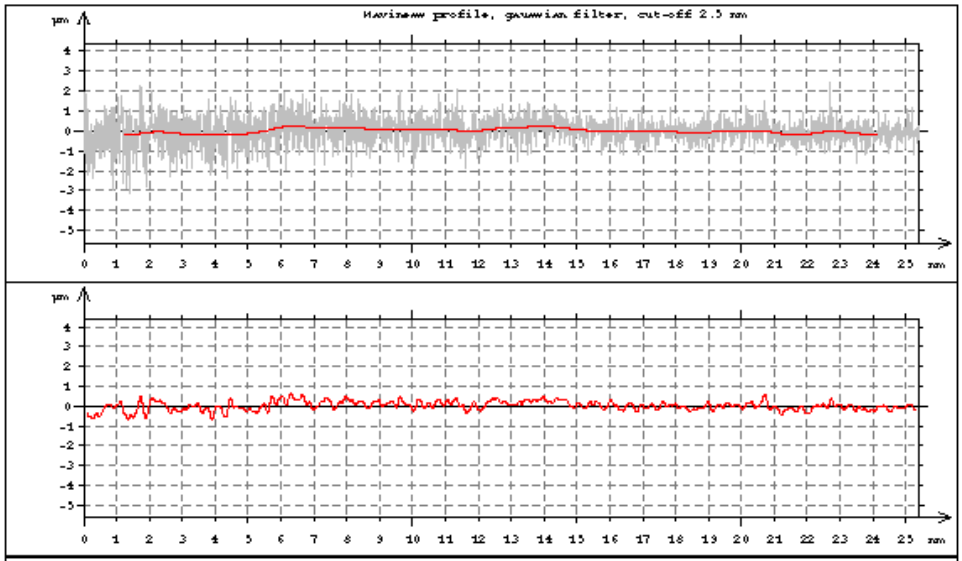
Roughness parameters, Gaussian filter, 0.12 mm

Rq = 0.479 µm
Root-Mean-Square (RMS) Deviation of the assessed (roughness) Profile
Rz = 1.82 µm
Maximum Height of (roughness) Profile
Rt = 12 µm
Total Height of (roughness) Profile
RPC = 0.791 pks/cm (+/- 2.5 µm)
Peak Count on the (roughness) Profile

Identity card

Name: 1200Hz16 > Levelled
Created on: 00/02/10 11:34:28

Axis: X
Length: 25.4 mm
Size: 3907 points
Spacing: 6.5 µm
Axis: Z
Length: 19.2 µm
Size: 1198 digits
Spacing: 16 nm



Parameters calculated on the profile 1200Hz20 > Levelled

Profile shape on slit size scale

Waviness parameters, Gaussian filter, 2.5 mm

Wt = 0.46 µm
Total Height of (waviness) Profile

Profile roughness on pixel si:

Waviness parameters, Gaussian filter, 0.12 mm

Wq = 0.267 µm
Root-Mean-Square (RMS) Deviation of the assessed (waviness) Profile
Wz = 0.461 µm
Maximum Height of (waviness) Profile
Wt = 2 µm
Total Height of (waviness) Profile
WPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (waviness) Profile

sub-pixel microroughn

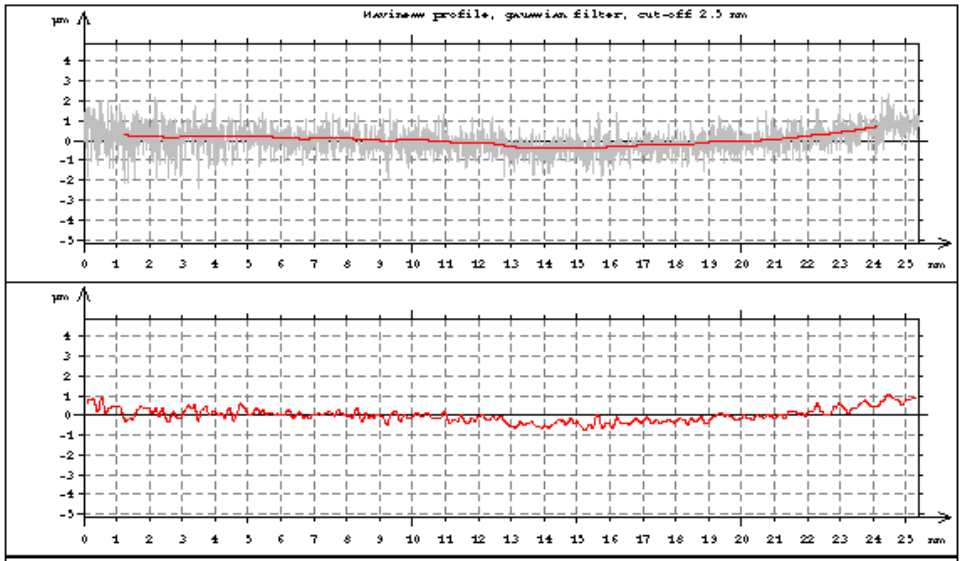
Roughness parameters, Gaussian filter, 0.12 mm

Rq = 0.417 µm
Root-Mean-Square (RMS) Deviation of the assessed (roughness) Profile
Rz = 1.59 µm
Maximum Height of (roughness) Profile
Rt = 3.99 µm
Total Height of (roughness) Profile
RPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (roughness) Profile

Identity card

Name: 1200Hz20 > Levelled
Created on: 00/02/10 11:38:09

Axis: X
Length: 25.4 mm
Size: 3907 points
Spacing: 6.5 µm
Axis: Z
Length: 5.57 µm
Size: 348 digits
Spacing: 16 nm



Parameters calculated on the profile 1200Hz24 > Levelled

Profile shape on slit size scale

Waviness parameters, Gaussian filter, 2.5 mm

Wt = 1.13 µm
Total Height of (waviness) Profile

Profile roughness on pixel si:

Waviness parameters, Gaussian filter, 0.12 mm

Wq = 0.337 µm
Root-Mean-Square (RMS) Deviation of the assessed (waviness) Profile
Wz = 0.43 µm
Maximum Height of (waviness) Profile
Wt = 2.29 µm
Total Height of (waviness) Profile
WPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (waviness) Profile

sub-pixel microroughn

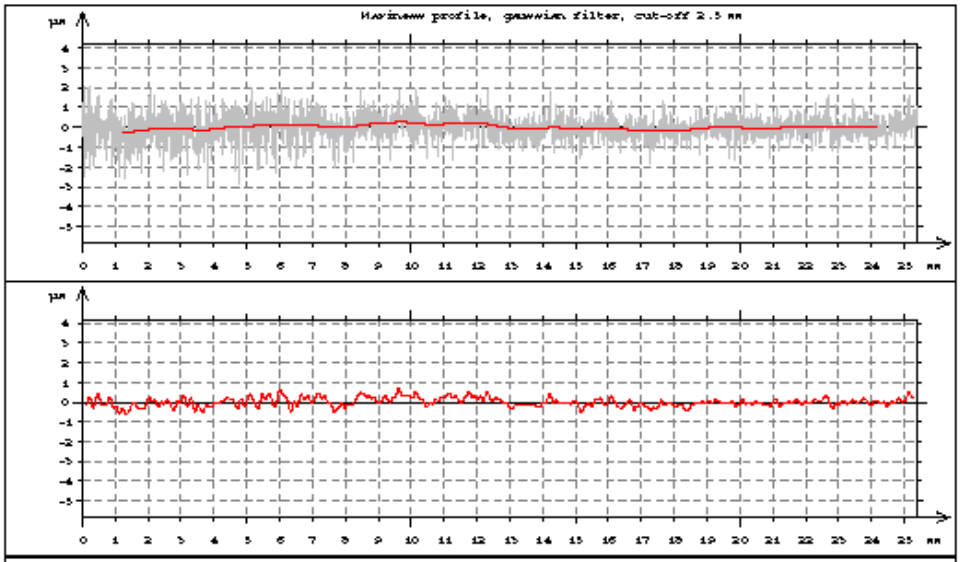
Roughness parameters, Gaussian filter, 0.12 mm

Rq = 0.369 µm
Root-Mean-Square (RMS) Deviation of the assessed (roughness) Profile
Rz = 1.4 µm
Maximum Height of (roughness) Profile
Rt = 3.67 µm
Total Height of (roughness) Profile
RPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (roughness) Profile

Identity card

Name: 1200Hz24 > Levelled
Created on: 00/02/10 11:41:30

Axis: X
Length: 25.4 mm
Size: 3907 points
Spacing: 6.5 µm
Axis: Z
Length: 4.75 µm
Size: 297 digits
Spacing: 16 nm



Parameters calculated on the profile 1200Hz28 > Levelled

Profile shape on slit size scale

Waviness parameters, Gaussian filter, 2.5 mm

Wt = 0.511 µm
Total Height of (Waviness) Profile

Profile roughness on pixel si

Waviness parameters, Gaussian filter, 0.12 mm

Wq = 0.268 µm
Root-Mean-Square (RMS) Deviation of the assessed (Waviness) Profile
Wz = 0.48 µm
Maximum Height of (Waviness) Profile
Wt = 1.94 µm
Total Height of (Waviness) Profile
WPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (Waviness) Profile

sub-pixel microroughn

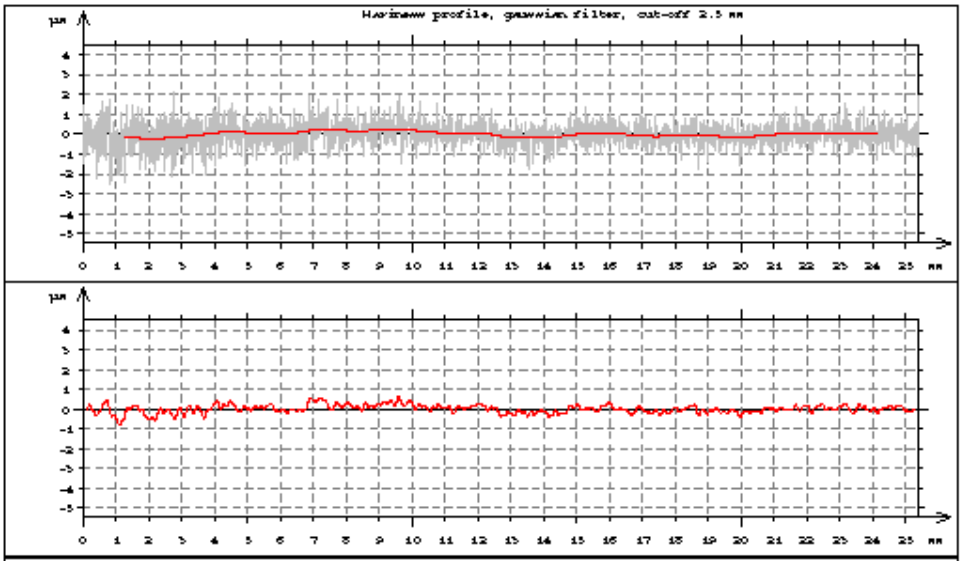
Roughness parameters, Gaussian filter, 0.12 mm

Rq = 0.419 µm
Root-Mean-Square (RMS) Deviation of the assessed (roughness) Profile
Rz = 1.57 µm
Maximum Height of (roughness) Profile
Rt = 4.1 µm
Total Height of (roughness) Profile
RPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (roughness) Profile

Identity card

Name: 1200Hz28 > Levelled
Created on: 00/02/10 11:44:55

Axis: X
Length: 25.4 mm
Size: 3907 points
Spacing: 6.5 µm
Axis: Z
Length: 5.04 µm
Size: 315 digits
Spacing: 16 nm



Parameters calculated on the profile 1200Hz32 > Levelled

Profile shape on slit size scale

Waviness parameters, Gaussian filter, 2.5 mm

Wt = 0.499 µm
Total Height of (waviness) Profile

Profile roughness on pixel si:

Waviness parameters, Gaussian filter, 0.12 mm

Wq = 0.238 µm
Root-Mean-Square (RMS) Deviation of the assessed (waviness) Profile
Wz = 0.431 µm
Maximum Height of (waviness) Profile
Wt = 2.11 µm
Total Height of (waviness) Profile
WPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (waviness) Profile

sub-pixel microroughn

Roughness parameters, Gaussian filter, 0.12 mm

Rq = 0.374 µm
Root-Mean-Square (RMS) Deviation of the assessed (roughness) Profile
Rz = 1.42 µm
Maximum Height of (roughness) Profile
Rt = 4.12 µm
Total Height of (roughness) Profile
RPC = 0 pks/cm (+/- 2.5 µm)
Peak Count on the (roughness) Profile

Identity card

Name: 1200Hz32 > Levelled
Created on: 00/02/10 11:48:12

Axis: X
Length: 25.4 mm
Size: 3907 points
Spacing: 6.5 µm
Axis: Z
Length: 4.67 µm
Size: 292 digits
Spacing: 16 nm