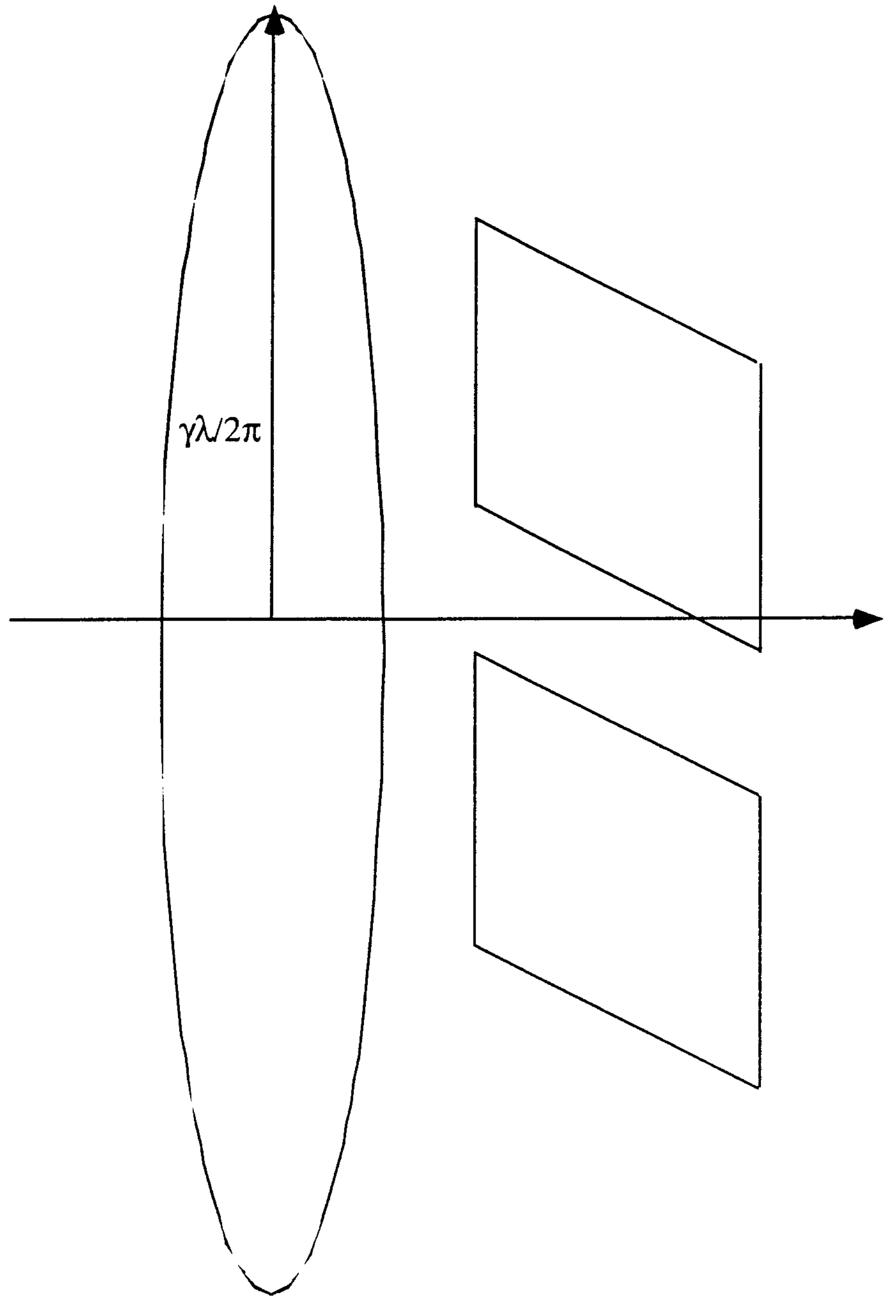
Bunch Length Measurement with Coherent Diffraction Radiation

M. Castellano, L. Catani[#], A. Cianchi[#], M. Geitz[$], G. Orlandi[#],
V. Verzilov

INFN-LNF
INFN-Roma2
$ DESY

TTF Meeting - Argonne 8-10/11/1999

Diffraction Radiation



Bunch Length measurement

It is a well known notion that the bunch longitudinal form factor (the Fourier transform of the longitudinal charge distribution) can be obtained from the spectrum of the coherent transition radiation.
This spectrum can be obtained in the time domain by means of a Michelson-like interferometer.
The Coherent Diffraction Radiation (CDR) can give the same information, provided that the spectrum is not strongly depressed, with the advantage of not having material on the beam path.

I have proposed this technique for measurements on TTF at the end of 1995

M. Castellano - Diffraction Radiation as a non-intercepting diagnostics for TTF: the bunch length measurement
TESLA 96-08 (1996)

The use of this technique has been considered in the TESLA CDR

The first (**and unique**) experimental evidence of CDR emission has been obtained in 1995

Y. Shibata et all - Physical Review E <u>52</u>, 6787 (1995)

The interpretation of these results was made difficult by the interference between Diffraction Radiation and Transition Radiation from a mirror required to extract the radiation from the vacuum pipe.

In there analysis the authors also ignored the effects of the screen finite size, as was noted in a later paper:

N.F. Shul'ga and S.N. Dobrovol'ski - JEPT Lett. 65, 611 (1997)

This effect has been recently fully analyzed in a paper of our group:

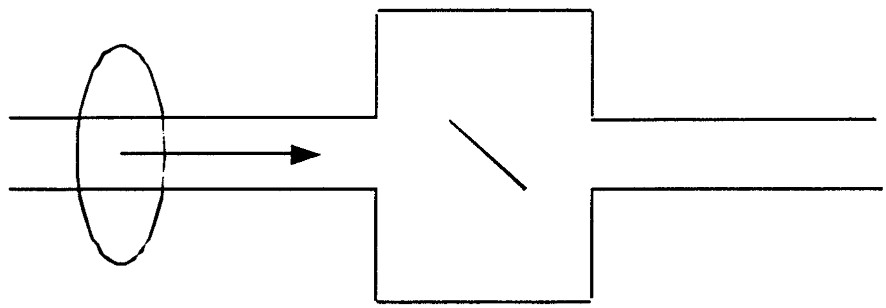
M. Castellano et all. - NIM A435, 297 (1999)

Walter Barry has presented a qualitative discussion of the use of CDR for bunch length measurement:

W. Barry - Measurements of Subpicosecond Bunch Profile Using Coherent Transition Radiation
Proceedings of Seventh Beam Instrumentation Workshop
AIP Conference Proceedings 390, 173 (1996)

Our results are the first real experimental evidence of the use of CDR for bunch length measurement

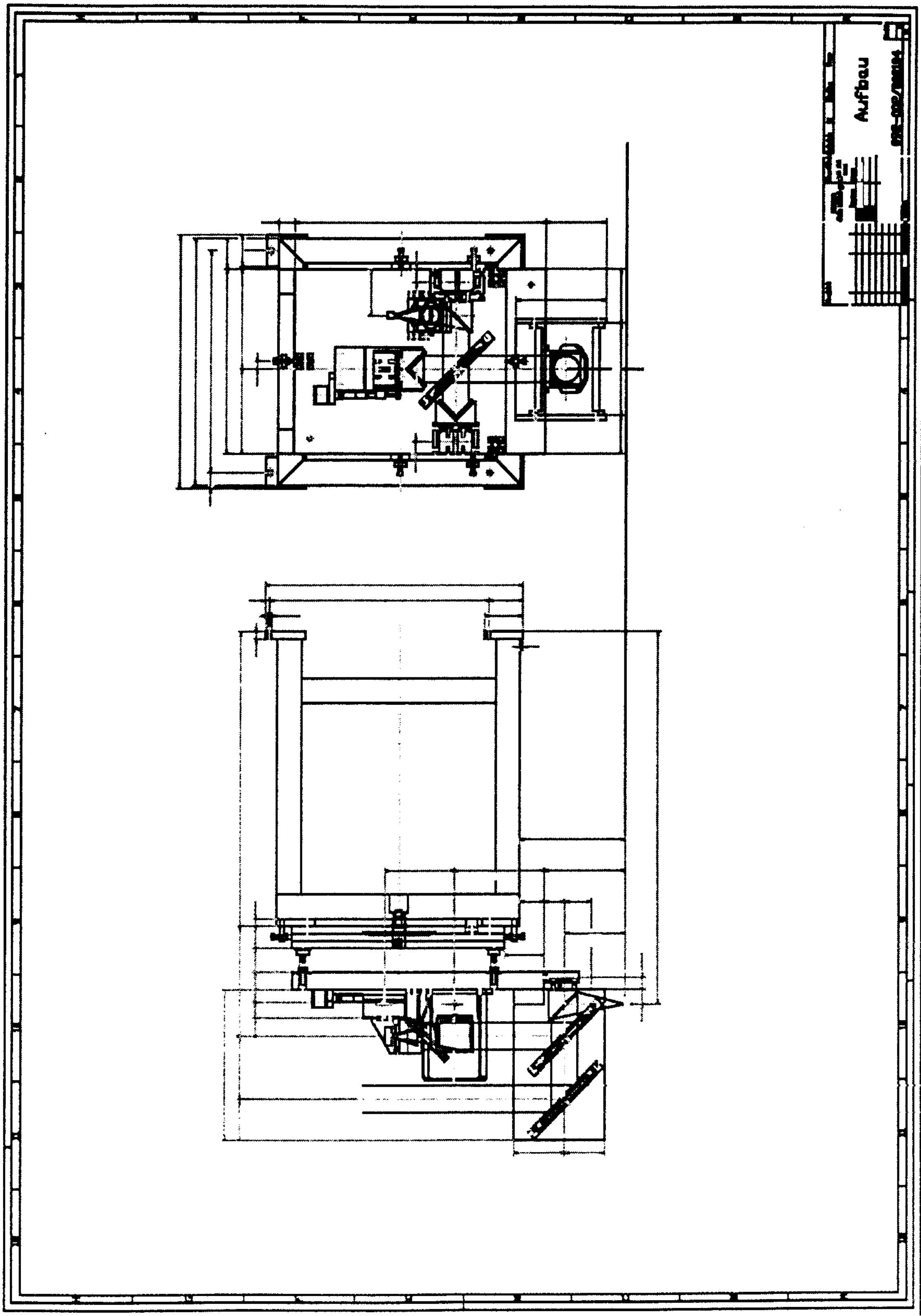
Problems common to standard long wavelength Transition Radiation



With γ=450 and wavelengths of the order of 1 mm, the extension of the particle EM field is larger than the pipe radius, so that wakefields are created. Furthermore, in entering the screen vacuum chamber, diffraction radiation is produced.
These radiations can be reflected by the screen and interfere with the radiation produced by the screen itself.

We must be careful about what kind of radiation is detected.

The optical set-up of the interferometer helps in selecting the radiation source.


Aufbau

The Diffraction Radiation Screen

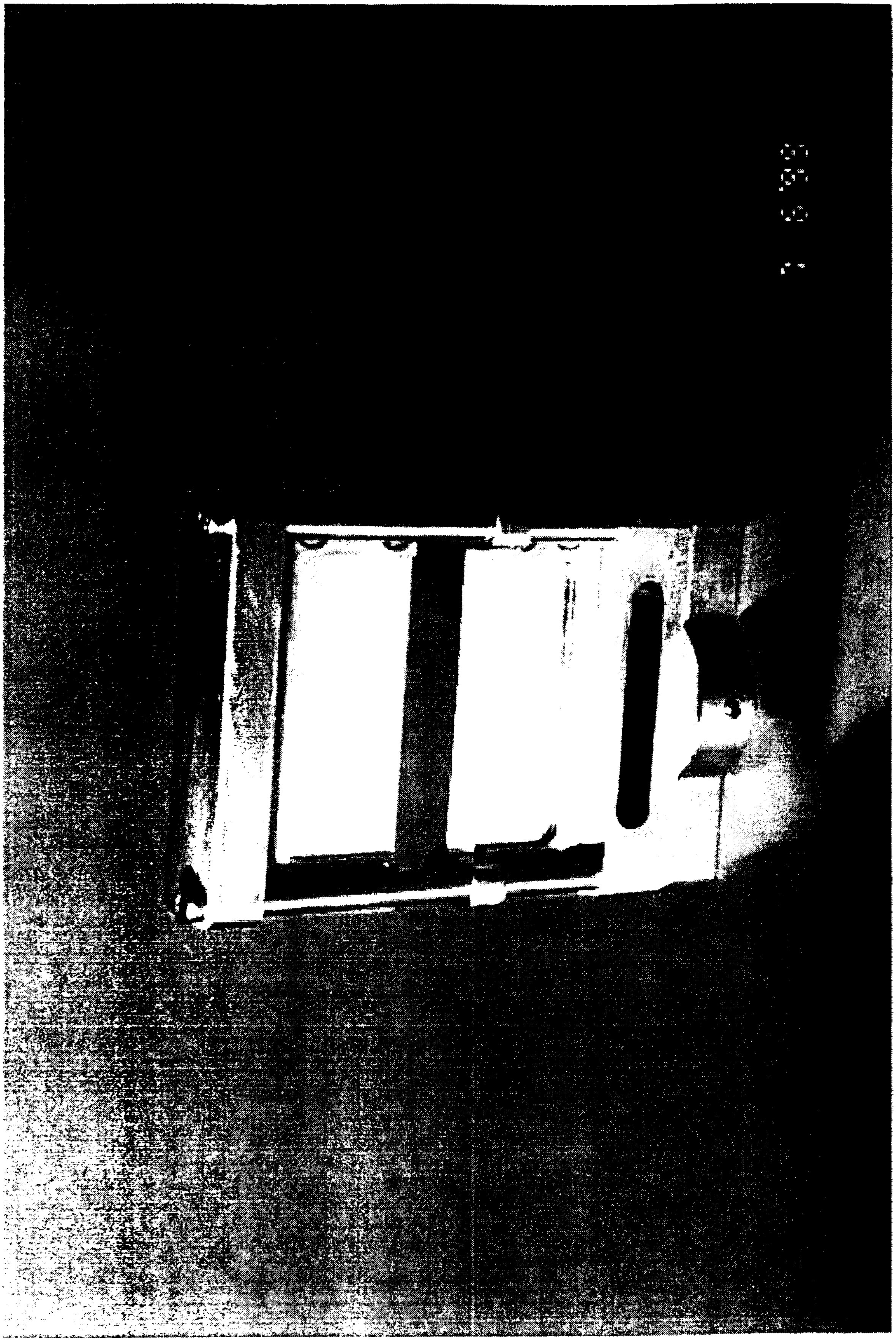
The DR source consists of two independent coplanar rectangular screens that can be moved vertically one with respect to the other obtaining a variable width slit.

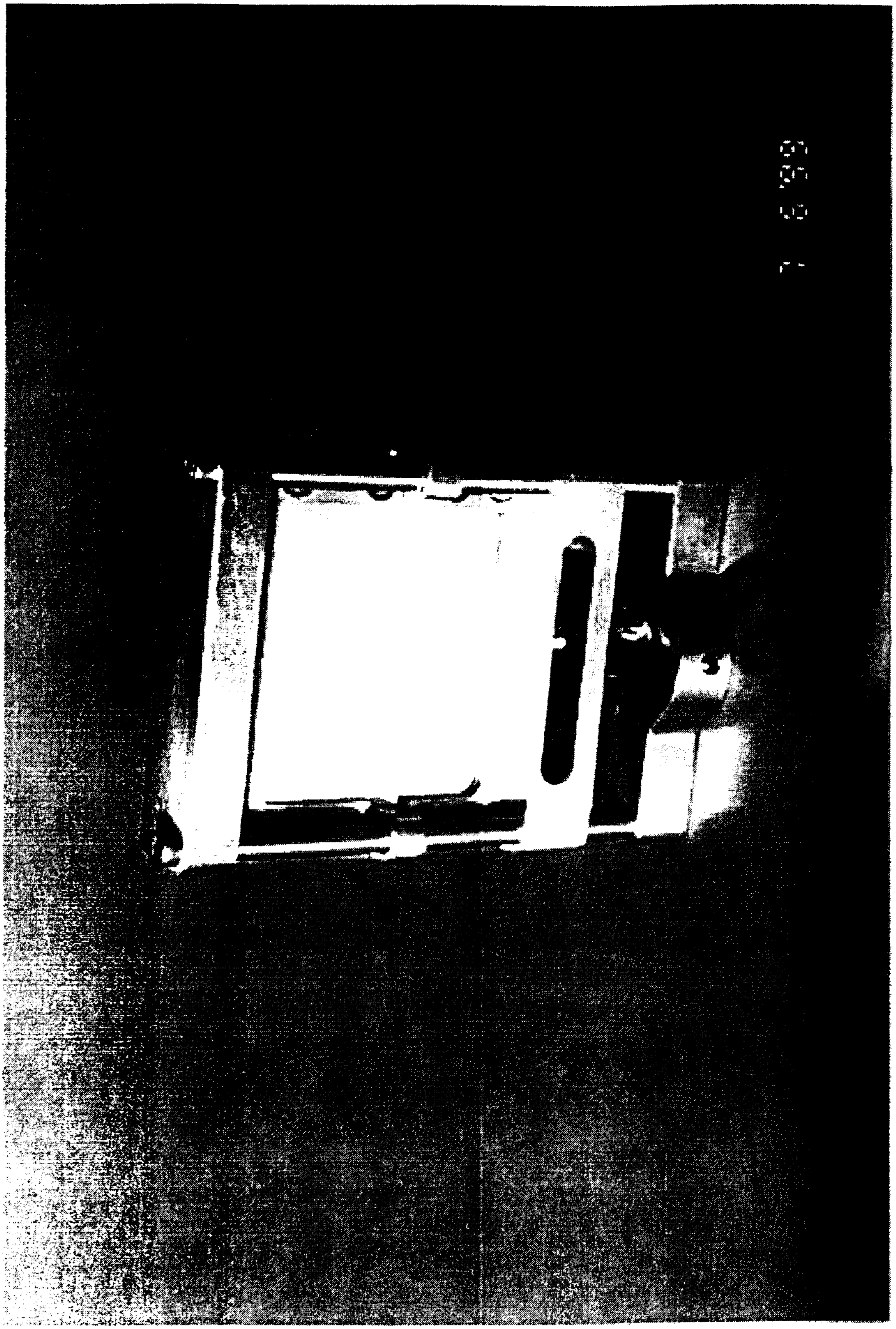
Each screen is a monocrystal Si wafer of 380 μm thickness, covered by a 100 nm Al film.

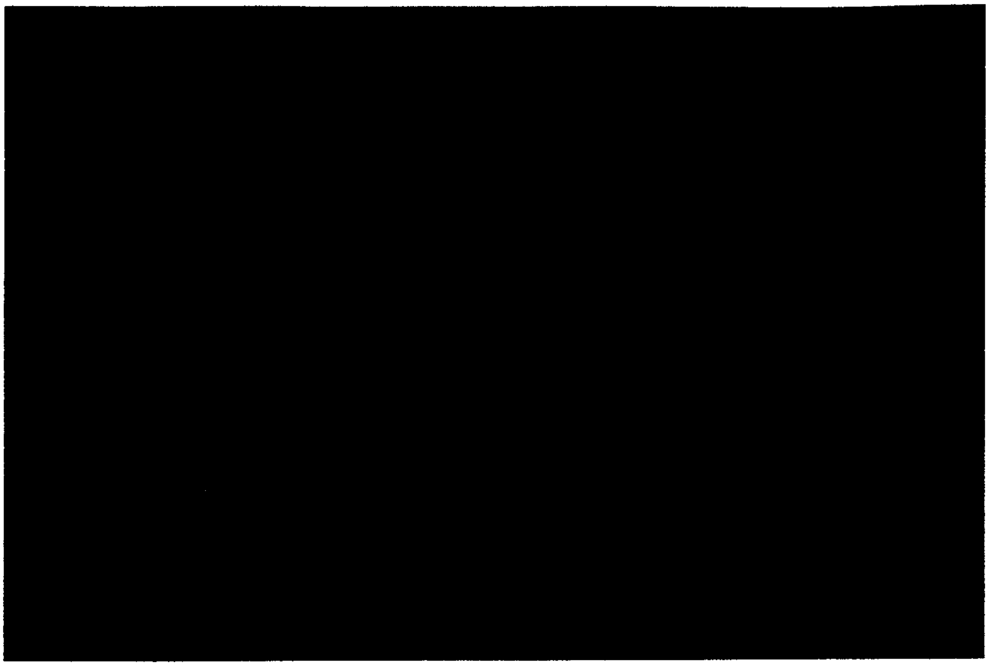
The reason of this choice was the impossibility of obtaining a good flatness from the standard Kapton foil used for the transition radiation screens.

The rms slit border roughness is 20 μm, and the overall planarity is within less than 2 mrad.

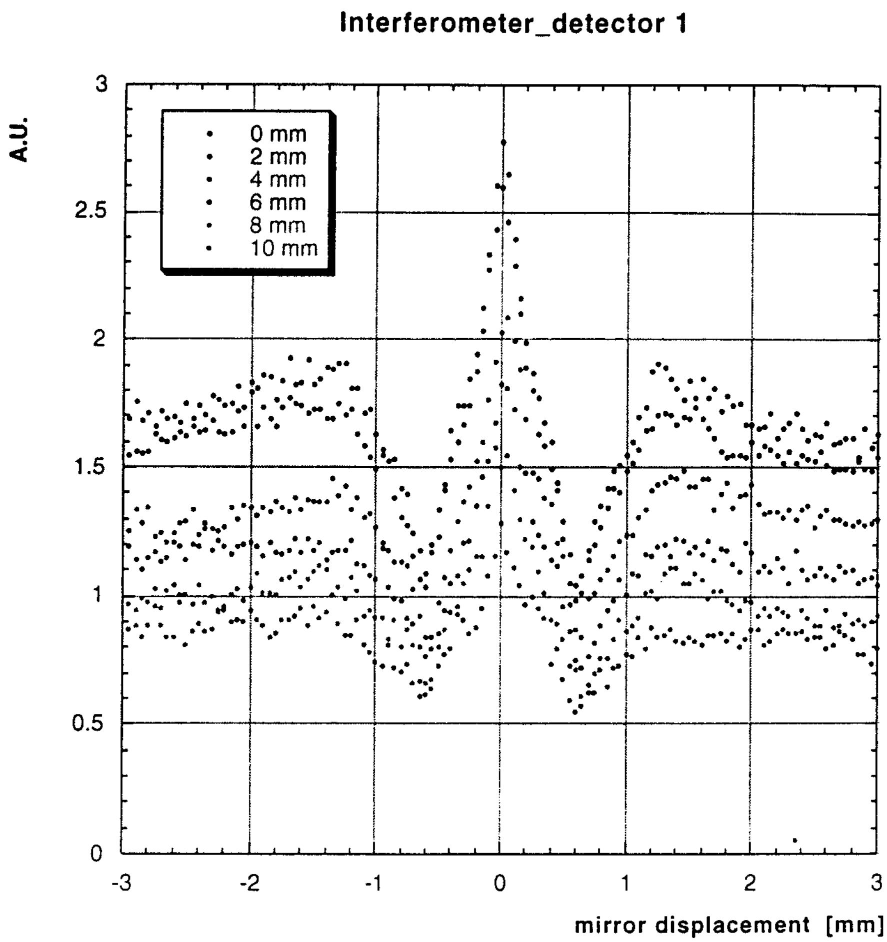
Two independent movements, driven by stepping motors, allow the insertion and removal from the beam line of the whole device, with a resolution in positioning of 5 μm/step, and the aperture of the slit, with a resolution of 2.5 μm/step.

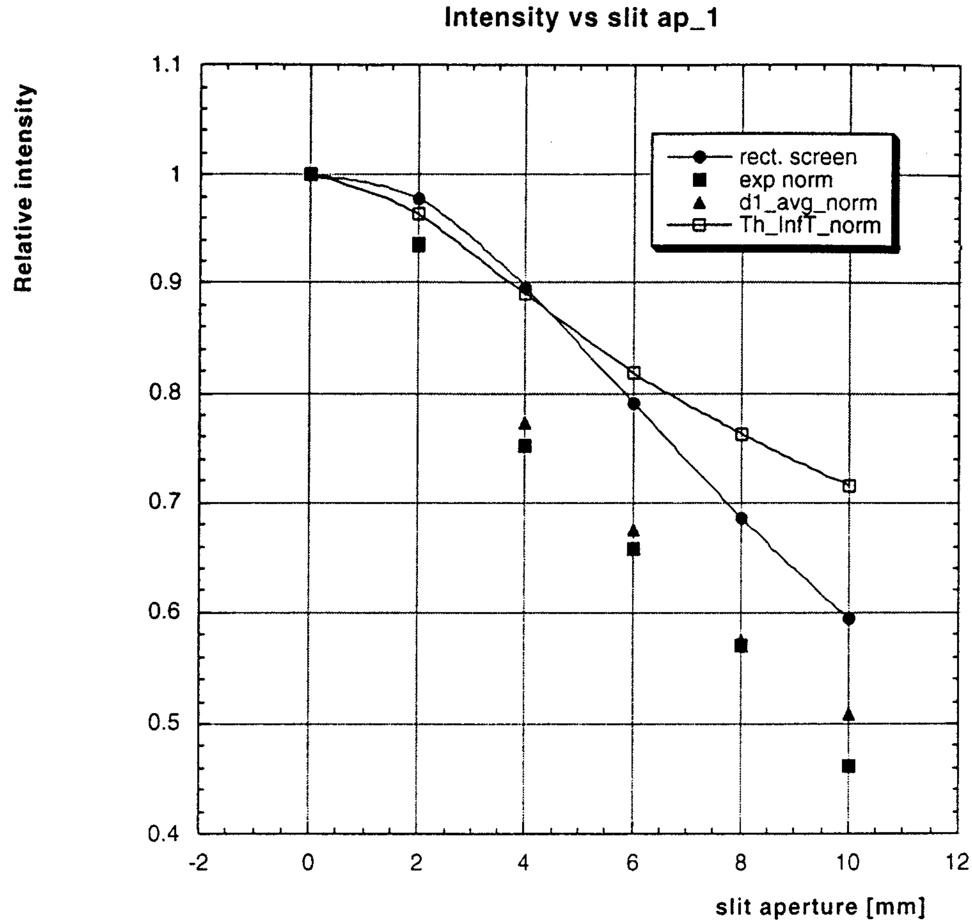




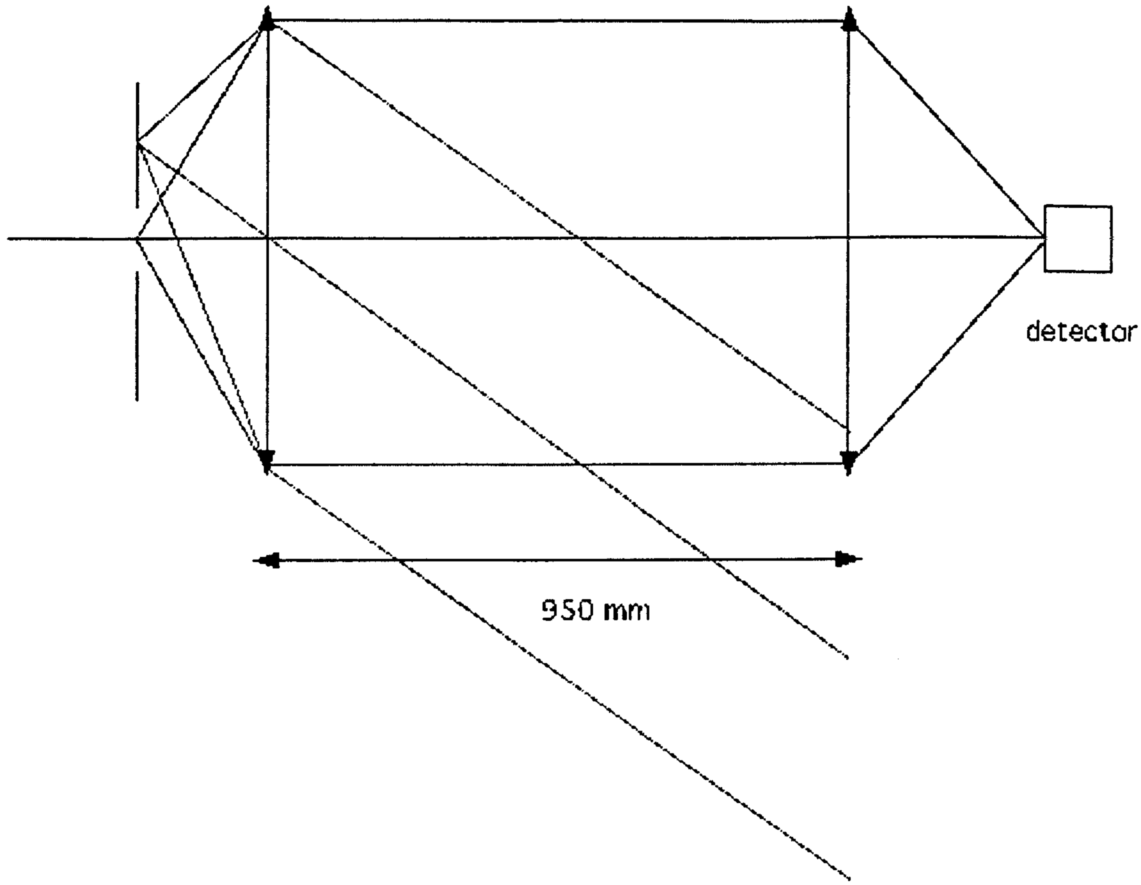


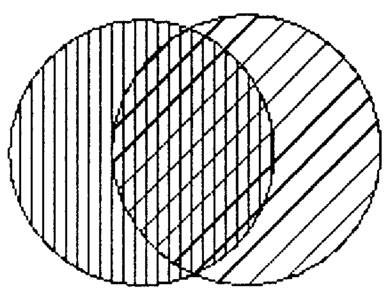
Single Laser Pulse	1 nC
σ_x (rms)	5 mm
σ_y	.6 mm

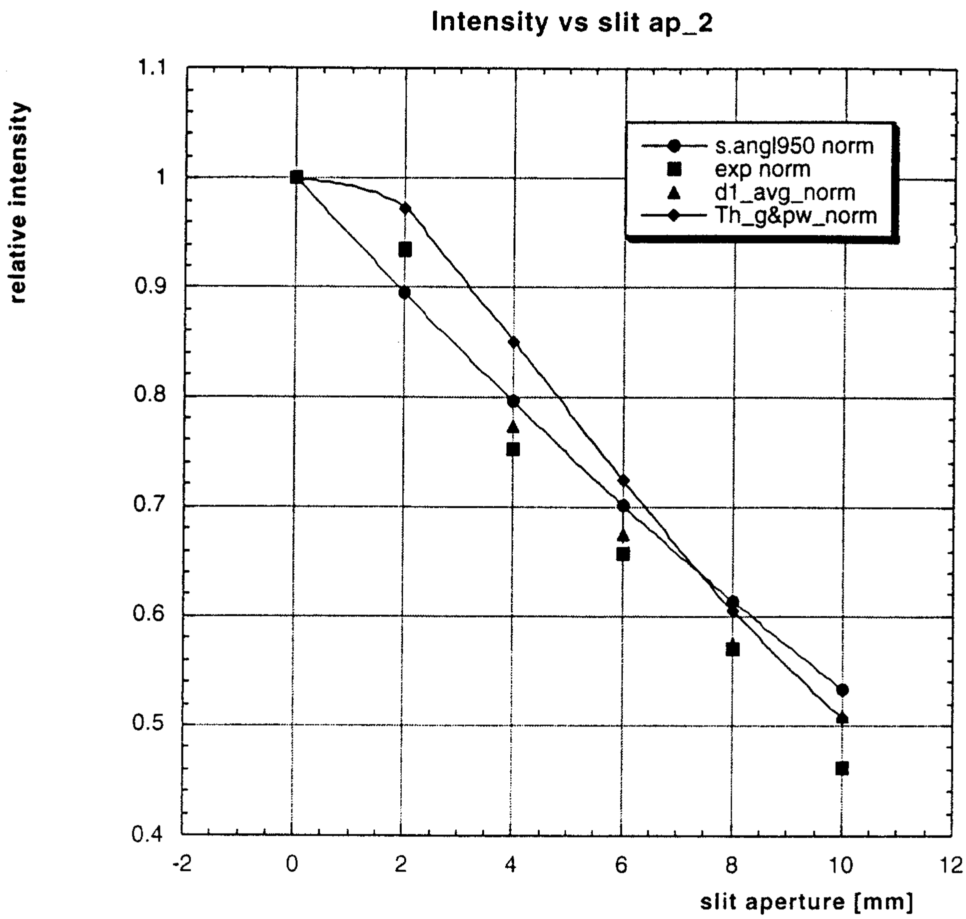

Interferometer_detector 1
A.U.
0 mm
2 mm
4 mm
6 mm
8 mm
10 mm
3
2.5
2
1.5
1
0.5
0
-3
-2
-1
0
1
2
3
mirror displacement [mm]

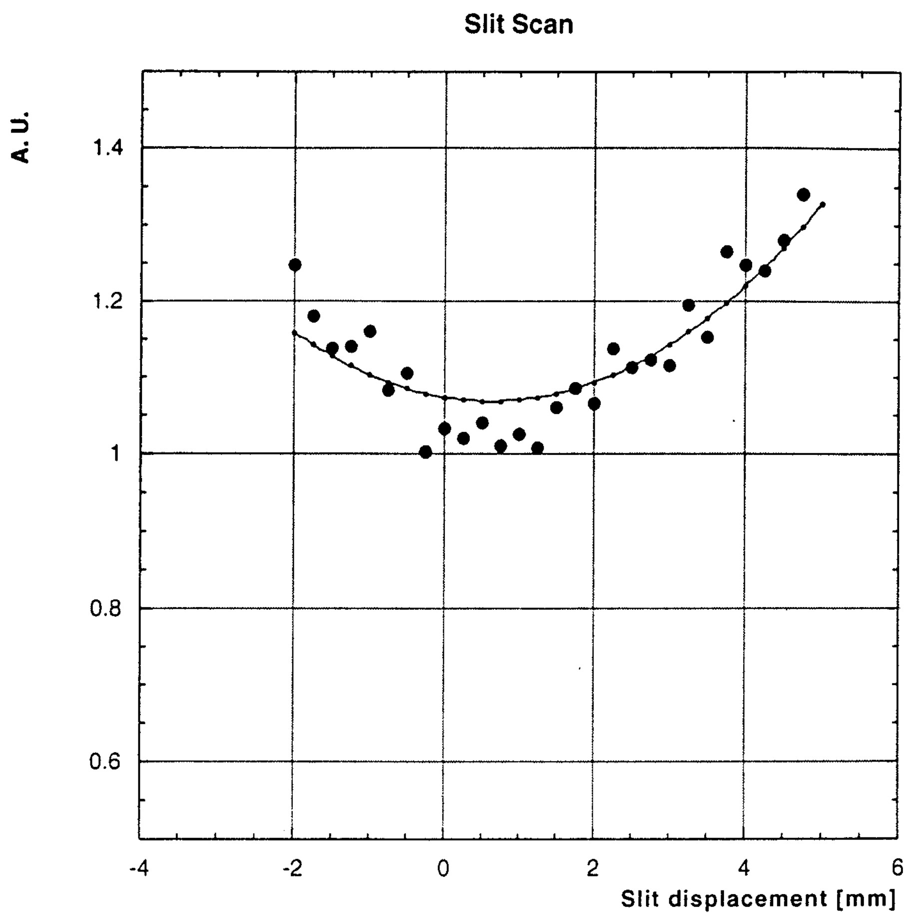


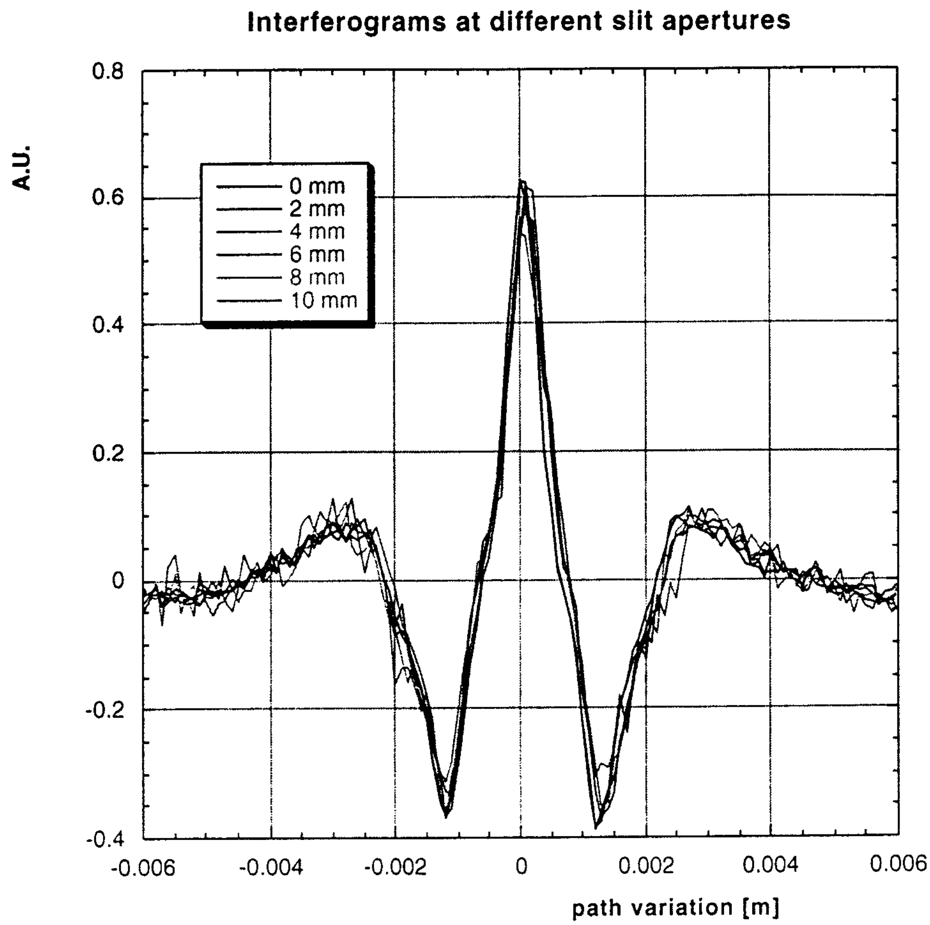
Intensity vs slit ap_1
Relative intensity
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
-2
0
2
4
6
8
10
12
slit aperture [mm]
rect. screen
exp norm
d1_avg_norm
Th_InfT_norm


detector
950 mm

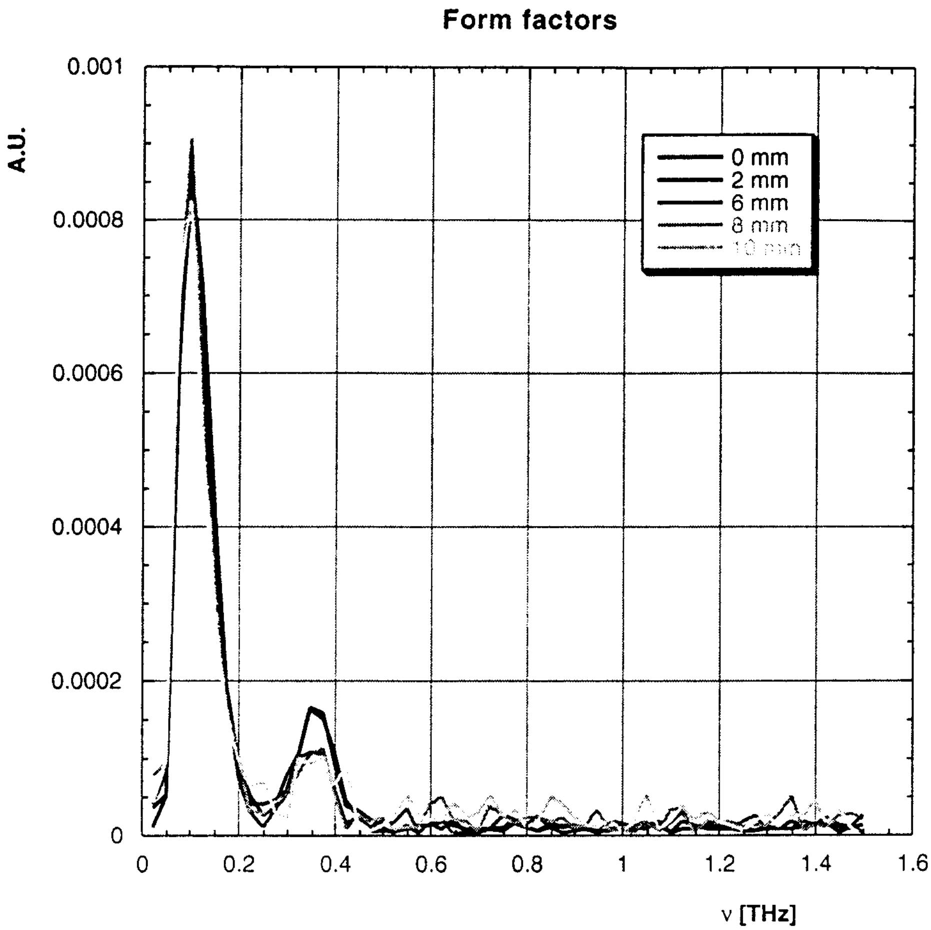



Intensity vs slit ap_2
relative intensity
slit aperture [mm]
s.angl950 norm
exp norm
d1_avg_norm
Th_g&pw_norm
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
-2
0
2
4
6
8
10
12


Slit Scan
A. U.
1.4
1.2
1
0.8
0.6
-4
-2
0
2
4
6
Slit displacement [mm]



Interferograms at different slit apertures
A.U.
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0 mm
2 mm
4 mm
6 mm
8 mm
10 mm
-0.006
-0.004
-0.002
0
0.002
0.004
0.006
path variation [m]


Form factors
A.U.
0.001
0.0008
0.0006
0.0004
0.0002
0
0 mm
2 mm
6 mm
8 mm
10 mm
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
ν [THz]

Bunch Length

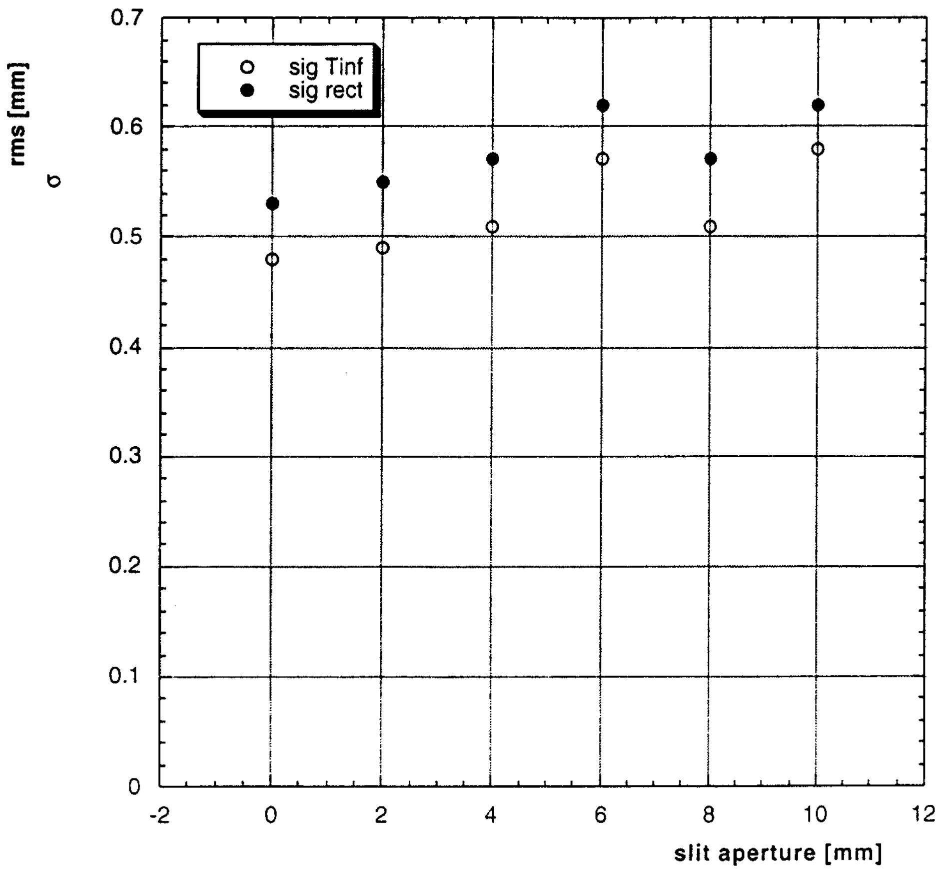
The spectra have been analyzed using a beam profile composed of two gaussian distribution. A single gaussian gives a bad fit.
The detector efficiency was taken into account, and two single-particle radiation distributions were compared:

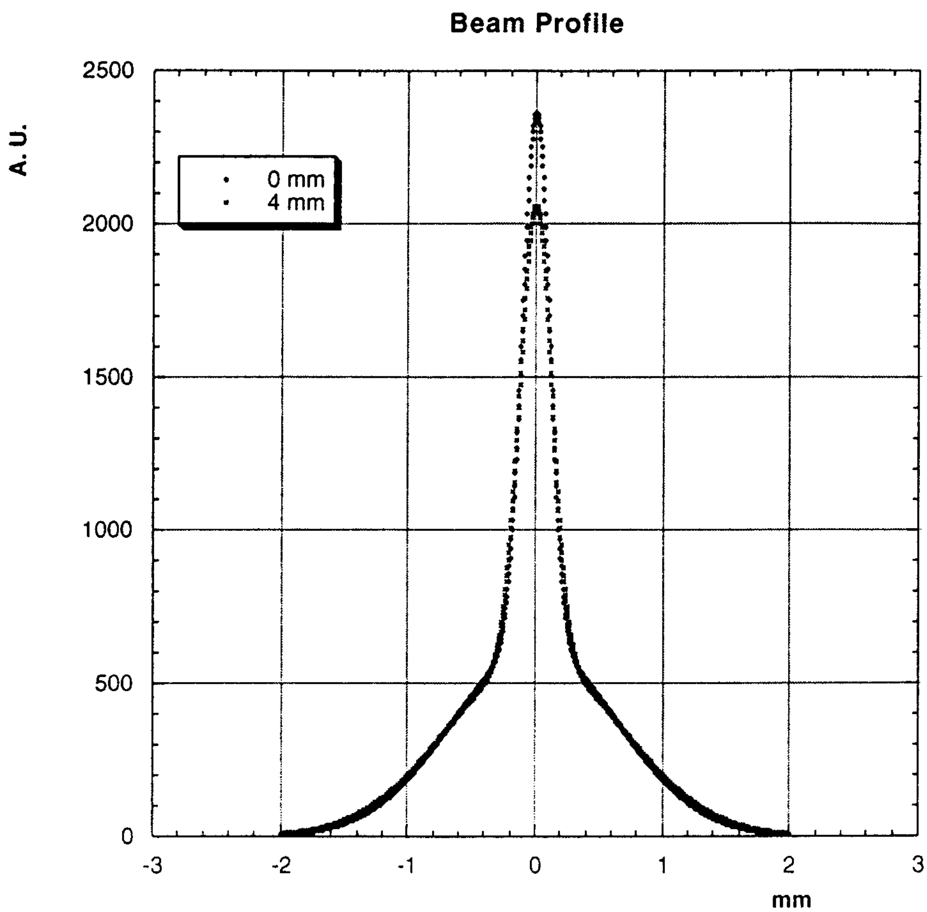
- from an infinite metallic foil (the standard solution)
- from a finite rectangular screen

For the moment no correction for the slit aperture has been introduced.

The correction factor due to the extended horizontal dimension of the beam is being evaluated, but it is expected to be small, even if not negligible.

Bunch length from diffraction radiation




Beam Profile
A. U.
0 mm
4 mm
2500
2000
1500
1000
500
0
-3
-2
-1
0
1
2
3
mm

CONCLUSIONS

For the first time Coherent Diffraction Radiation from a slit has been used to measure the bunch length.

These preliminary results confirm that the spectrum measured with the beam going through an open slit is equivalent to that produced by a standard transition radiation screen for bunch length measurements.

This opens the possibility of measuring the bunch length even with the long macropulse and full current.

If an enough fast detector can be found, a time resolved measurement would be also possible.