X-ray interferomety

for the FCC-ee

Self consistent analysis and proposal for testing using SuperKEKB X-ray monitor line

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1. **Brief introduction for interferometry in comparison with imaging**
2. **X-ray Interferometer for FCC-ee**
3. **Self consistent evaluation of average wavelength from interference fringe**
4. **Proposal for Test of the X-ray interferometry at the X-ray monitor beamline in the SuperKEKB**

Introduction to interferometry in comparison with imaging in inverse space

Input signal $\mathbf{g_0}$ in inverse space, given by $\mathbf{g_0} = \mathscr{F}(\mathbf{I_0})$ **is equal to the spatial coherence** $\boldsymbol{\gamma}$ through Van Cittelt-Zernike's theorem as follows;

$$\gamma = \iint \mathrm{I}(\mathbf{x_o}, \mathbf{y_o}) \exp\{-2\pi \mathbf{i} (\upsilon_x \mathbf{x_o} + \upsilon_y \mathbf{y_o})\} dx_0 dy_0$$

then $\mathbf{g_0} = \boldsymbol{\gamma}$.

So, we can measure image in inverse space without OTF by interferomtry.

Imaging with lens

Optical transfer function,
OTF (high cut filter)

input		output
g_0	$\longrightarrow \boxed{\mathscr{H}} \longrightarrow$	g_i

Interferometry

No loss in the
information

input		output
g_0	$\longrightarrow$	$g_i \cong g_0$

Imaging with lens

Optical transfer function, OTF

input | | output
$$g_0 \longrightarrow \boxed{\mathscr{H}} \longrightarrow g_i$$

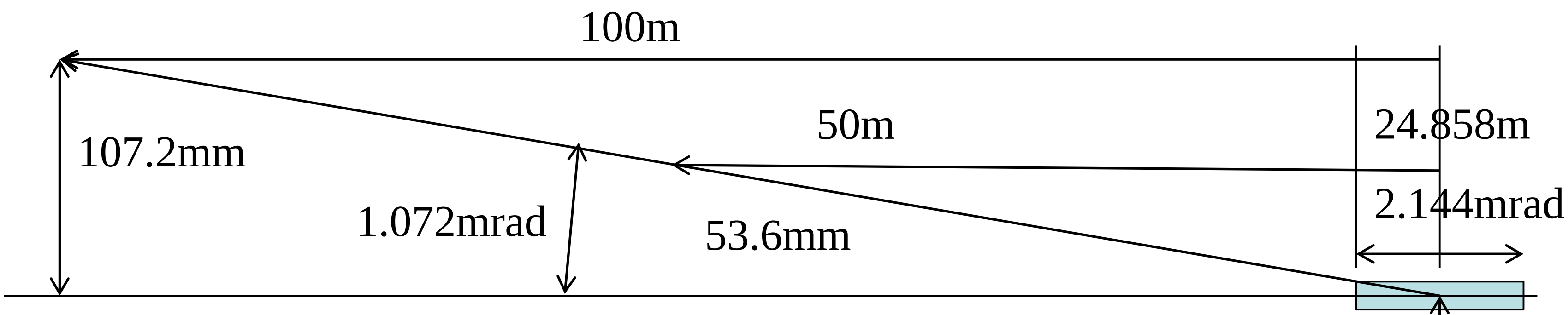
$$\Delta x \, \Delta\lambda \geq 1$$

Interferometry

input | | output
$$g_0 \longrightarrow g_i \cong g_0$$

$$\Delta I \, \Delta\phi \geq 1/2$$

X-ray Interferometer for FCC-ee



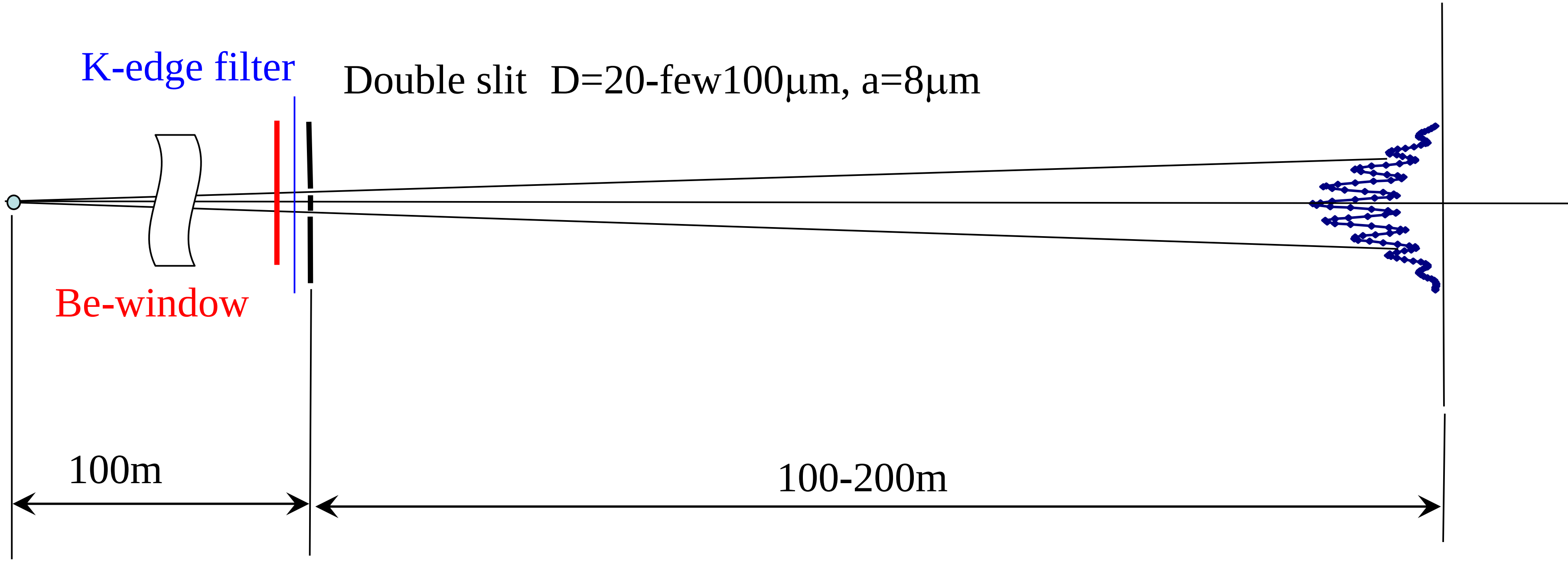
Geometrical condition for the extraction of SR from the last bending magnet

Bending radius 11590.8m

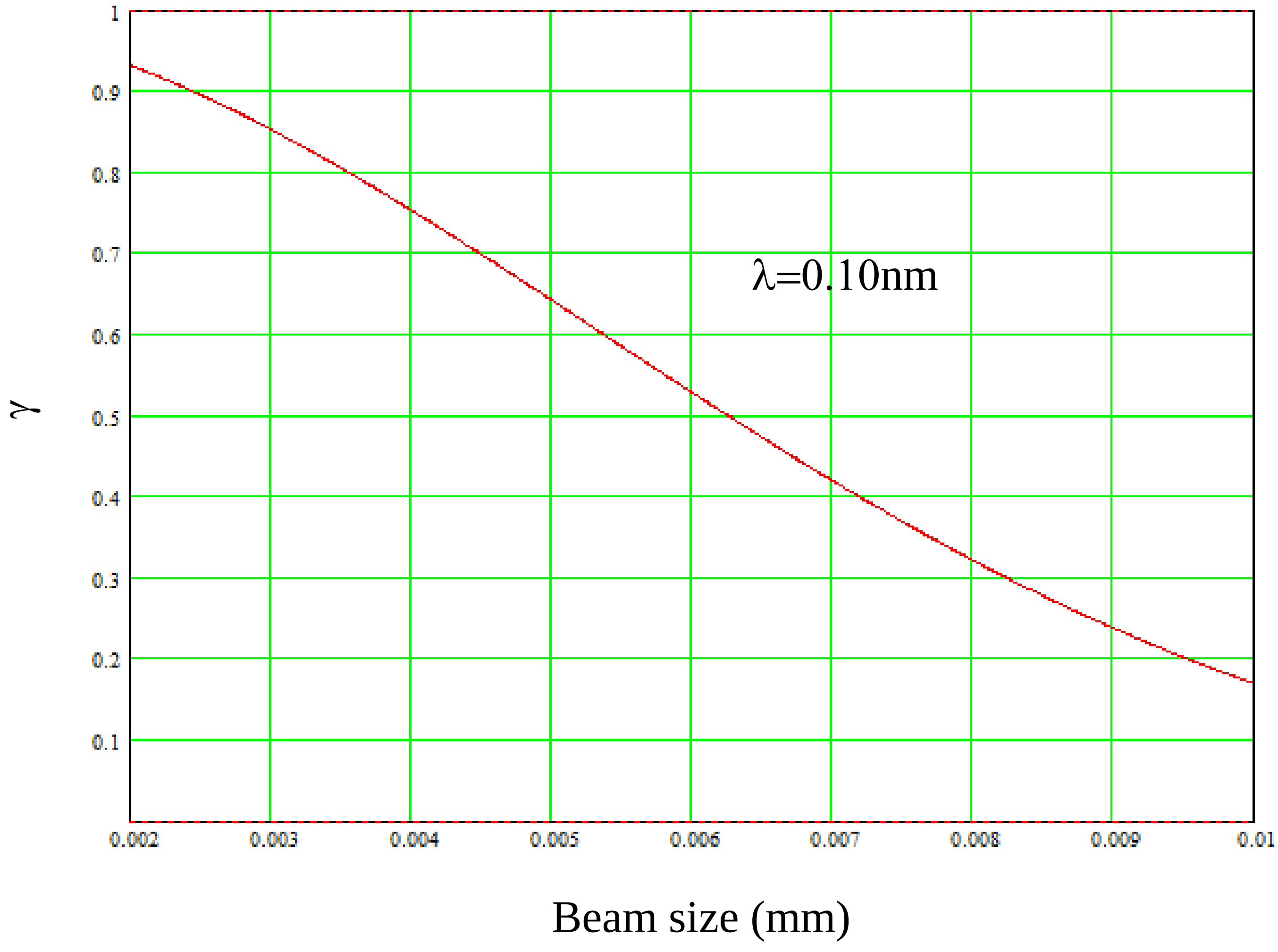
Possible distance between the source point to optical element is about 100m, and it is 10 times longer than existing machine.

10 times higher resolution is necessary in the FCC-ee

Simple double slit X-ray interferometer (Young type)

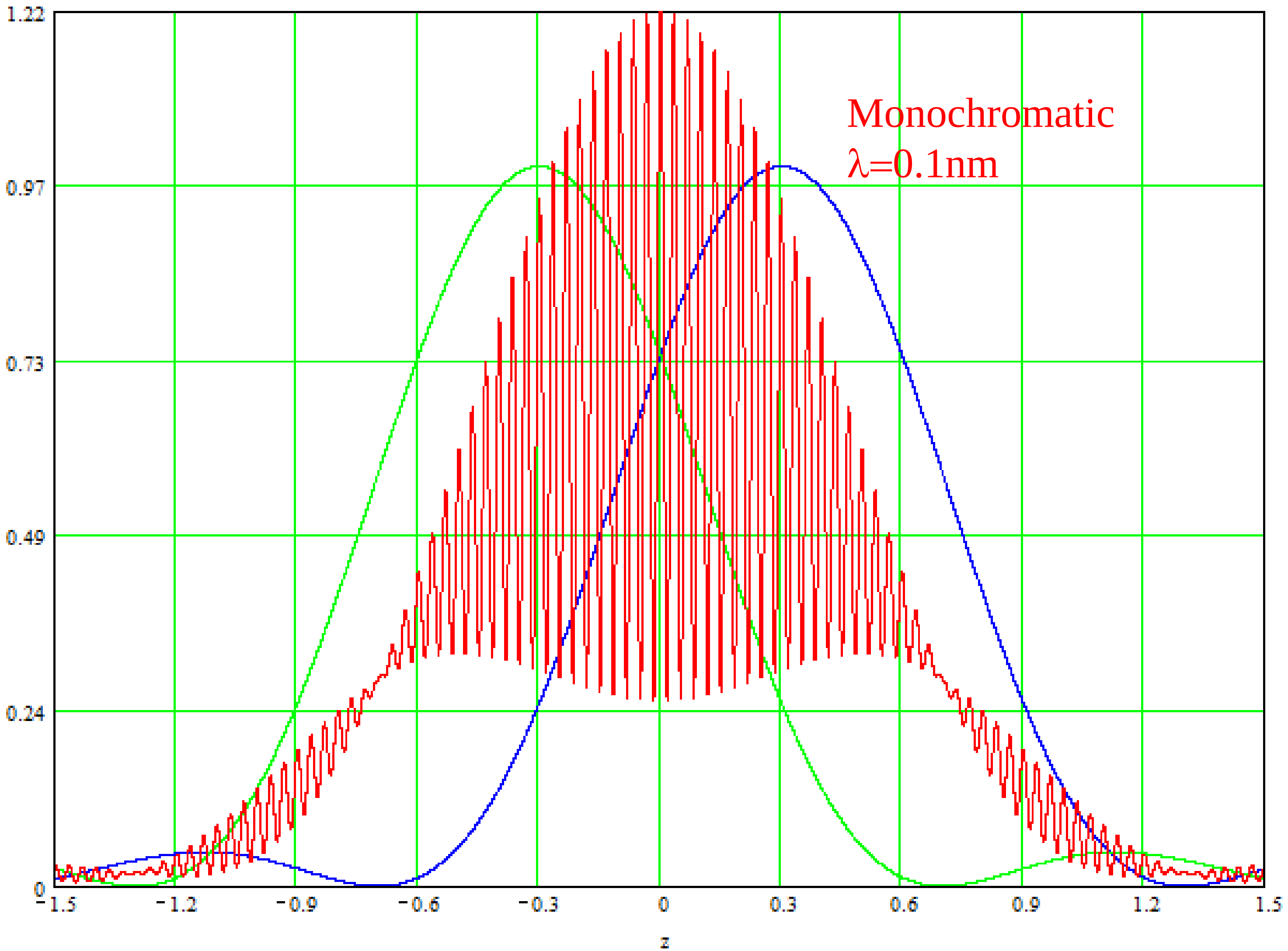


Spatial coherence vs. beam size D=300um, f=100m



Expected interferogram for γ=0.65 (beam size of 5μm at 100m)

Double slit a=5um, D=300um f=100m



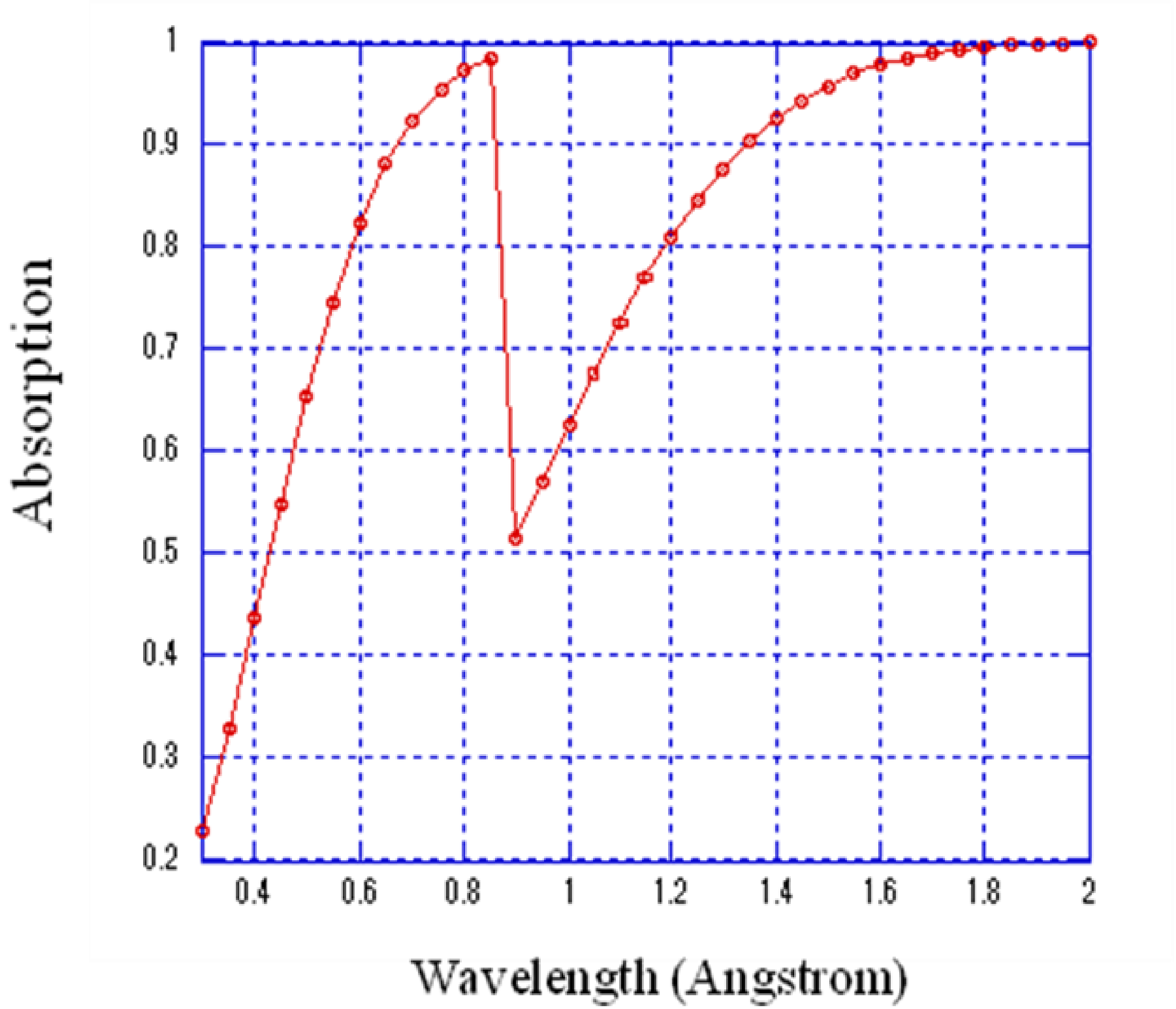
Important point

Different from using visible light, we have no variety choice of monochrometer in x-ray region!

We can use K-edge filter as about 20% bandwidth band-pass filter. By using this K-edge filter.

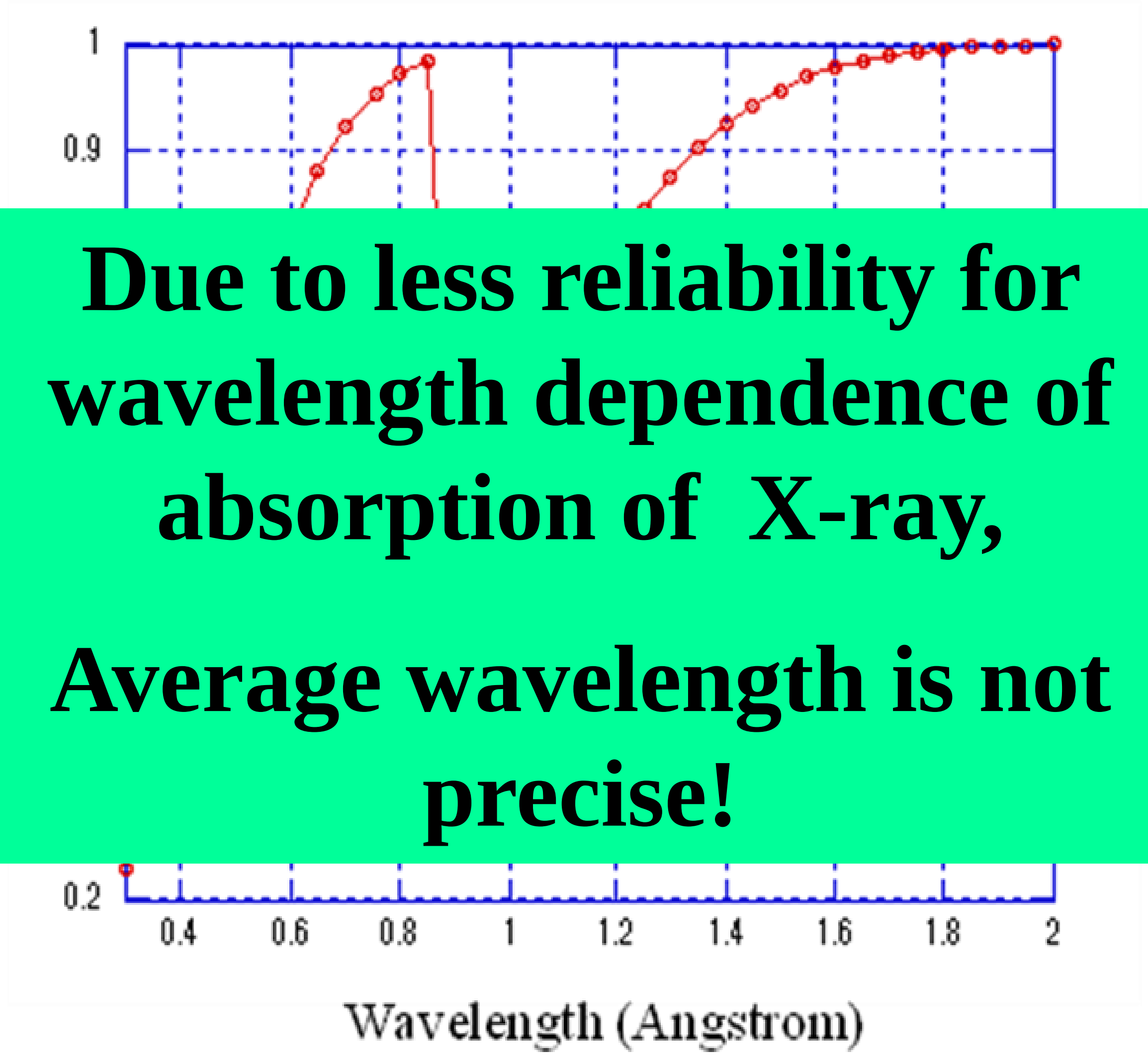
Off course we can use the crystal monochrometer, but bandwidth is typically $10^{-4\text{-}5}$ with Si or Ge single crystal monochrometer. Great reduction of intensity and almost useless!

Absorption of Krypton gas K-edge filter (1 atm, 100 mm pass).



Krypton gas filter has a nice window around 10keV

Absorption of Krypton gas K-edge filter (1 atm, 100 mm pass).



Due to less reliability for wavelength dependence of absorption of X-ray,

Average wavelength is not precise!

Krypton gas filter has a nice window around 10keV

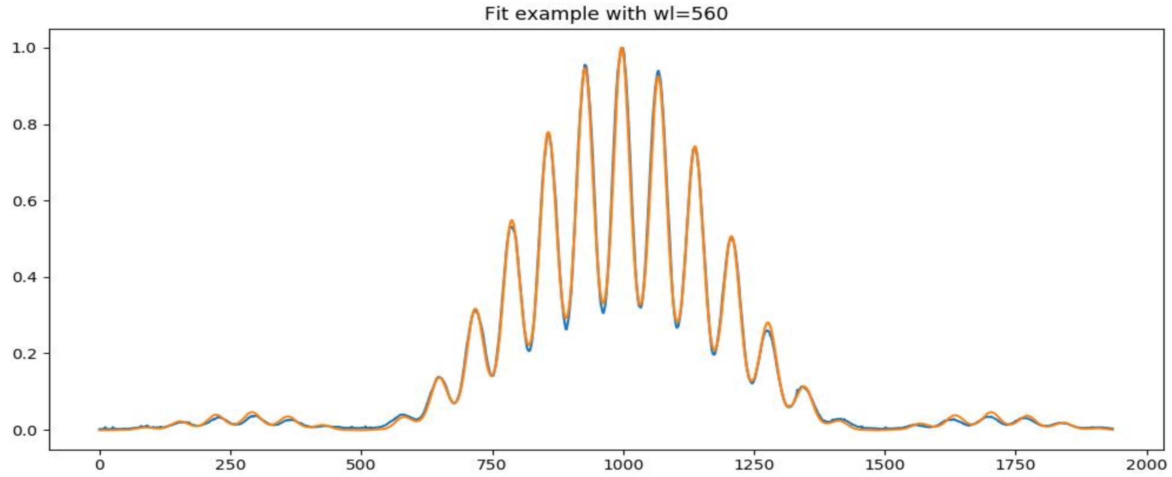
Self consistent evaluation of average wavelength from interference fringe.

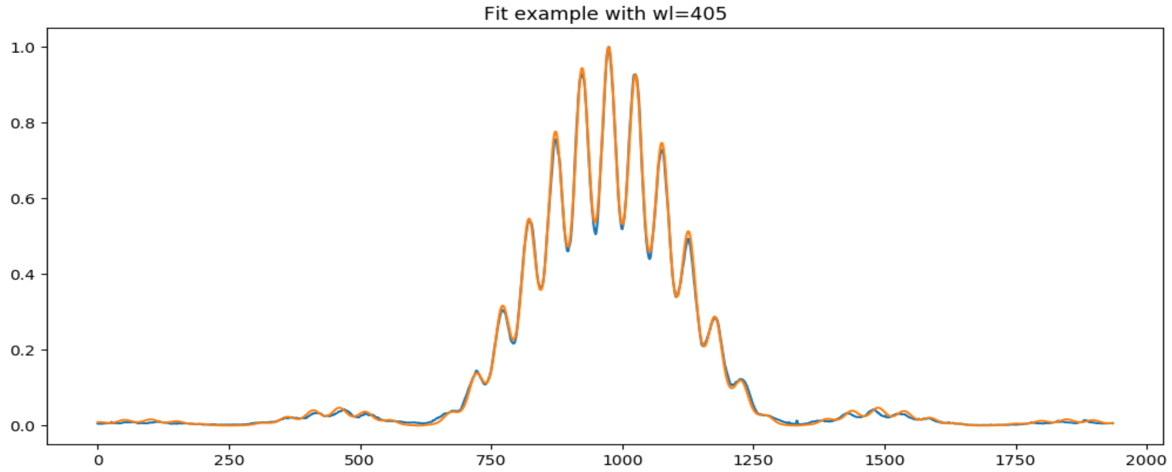
Since Interferometer is considered as equipment for *measurement absolute value of wavelength historically*.

The period of interference fringe is dominated by average wavelength. *So we can determine average wavelength from fringe period.*

Demonstration of evaluation for effective wavelength using interferogram data taken in LHC.

Two interferogram measured at LHC





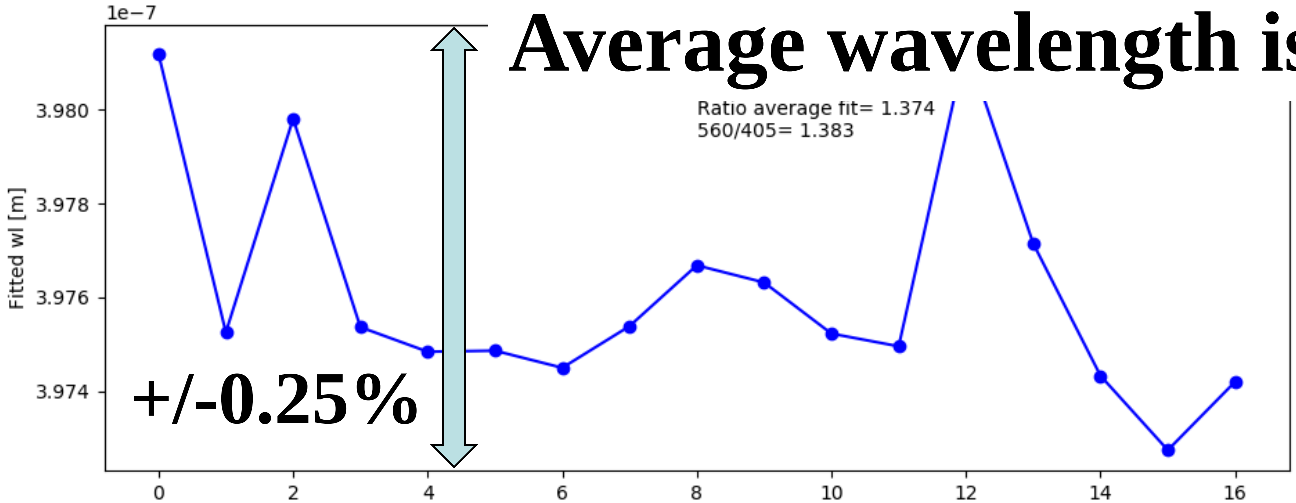
Following fitting function for interferogram is used for evaluate effective wavelength.

$$I(y, D) = (I_1 + I_2)\left\{\mathbf{sin}\,c\left(\frac{\pi a y}{\lambda_0 f}\right)\right\}\left\{1 + \gamma(D)\mathbf{cos}\left(kD\frac{y}{f} + \phi\right)\right\}$$

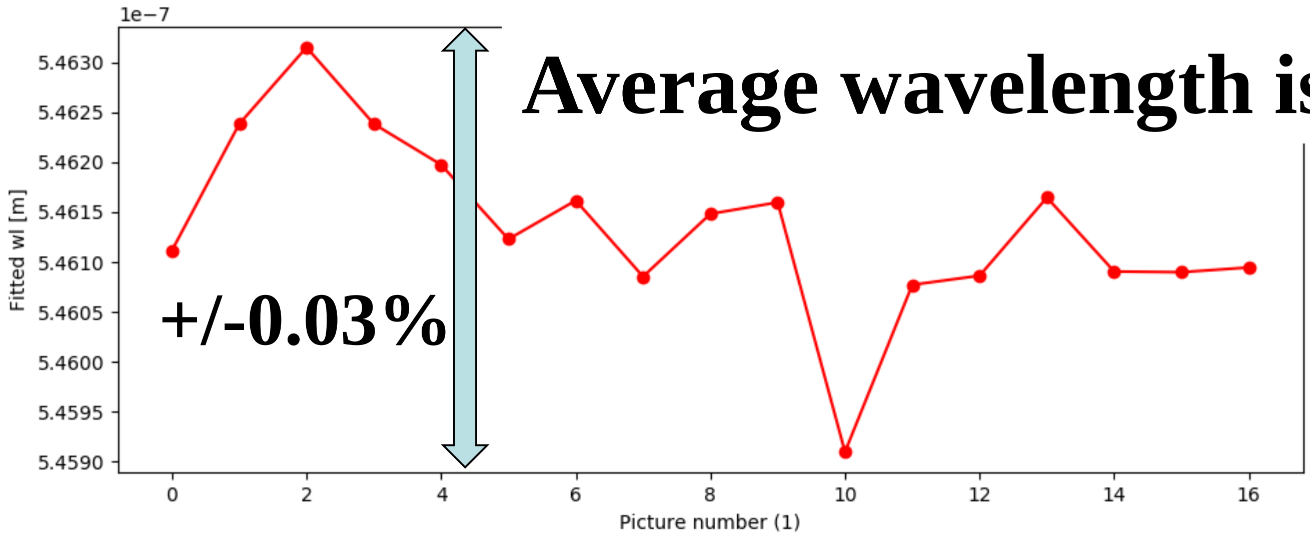
in here, $k = \dfrac{2\pi}{\lambda_0}$

Evaluated wavelength from 17 interferograms

Average wavelength is 397nm



Average wavelength is 546nm

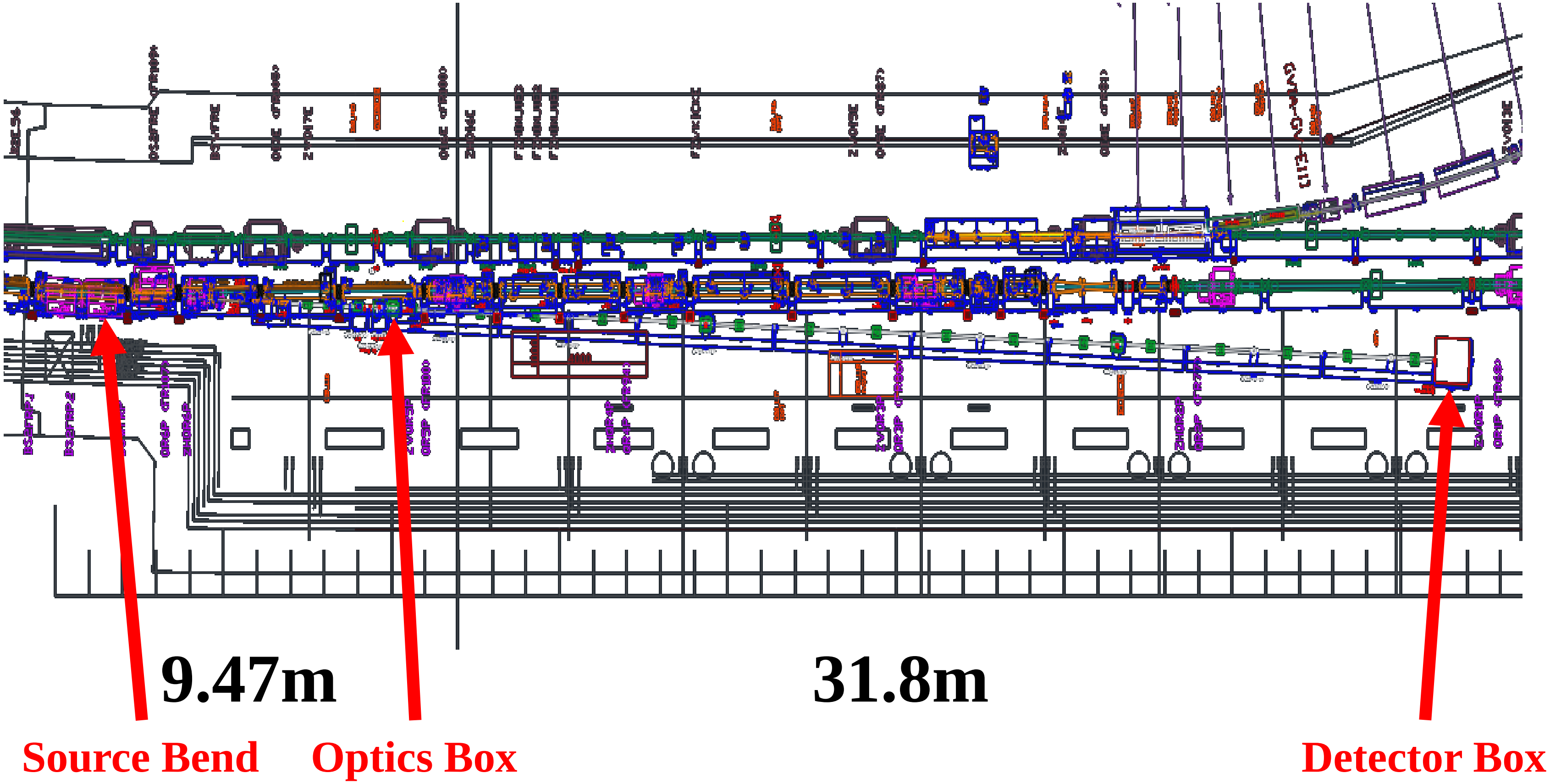


Proposal for Test of the X-ray interferometry at the X-ray monitor beamline in the SuperKEKB

Table 3.2: XRM beamline parameters in Phase 1 commissioning of SuperKEKB.

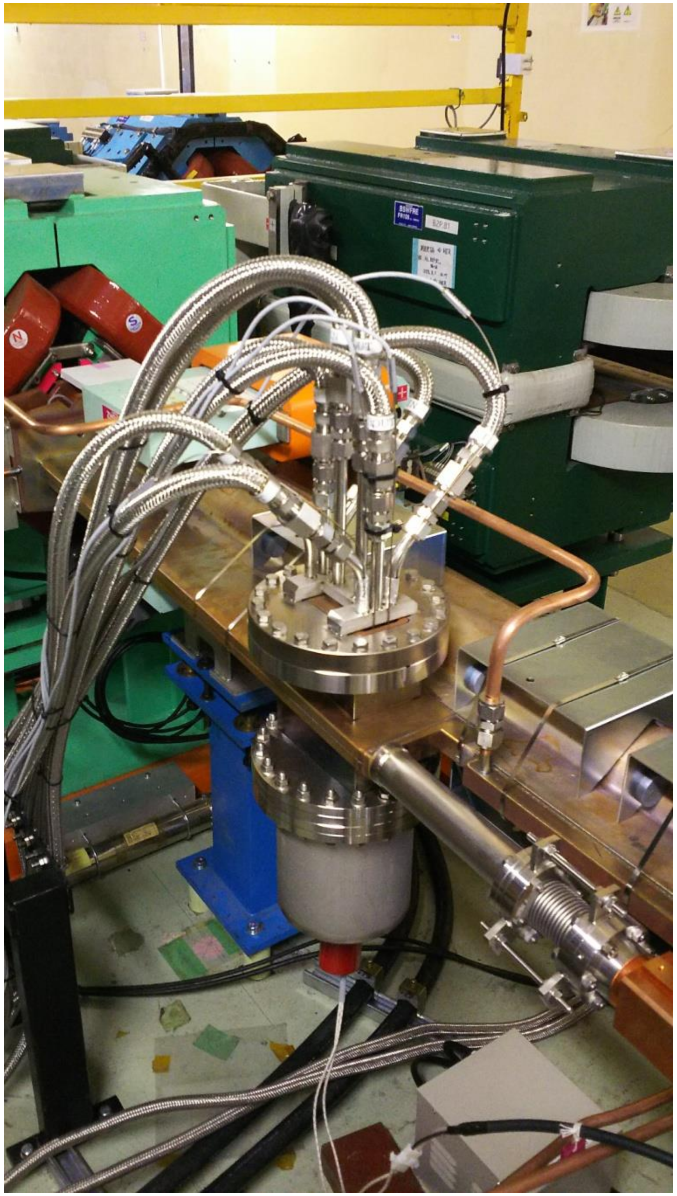
Parameter		LER (e^+)	HER (e^-)	Unit
Radius of source bend	ρ	31.85	105.98	m
Distance from source to optic	L	9.47	10.26	m
Distance from optic to Be window	L'	31.79	32.69	m
Thickness of Be filter	T	0.5	0.5	mm
Thickness of Be window	T'	0.2	0.2	mm
Thickness of Au		200	200	µm
Thickness of Diamond		600	600	µm
Air gap	f	100		mm
Effective thickness of YAG:Ce		141		µm

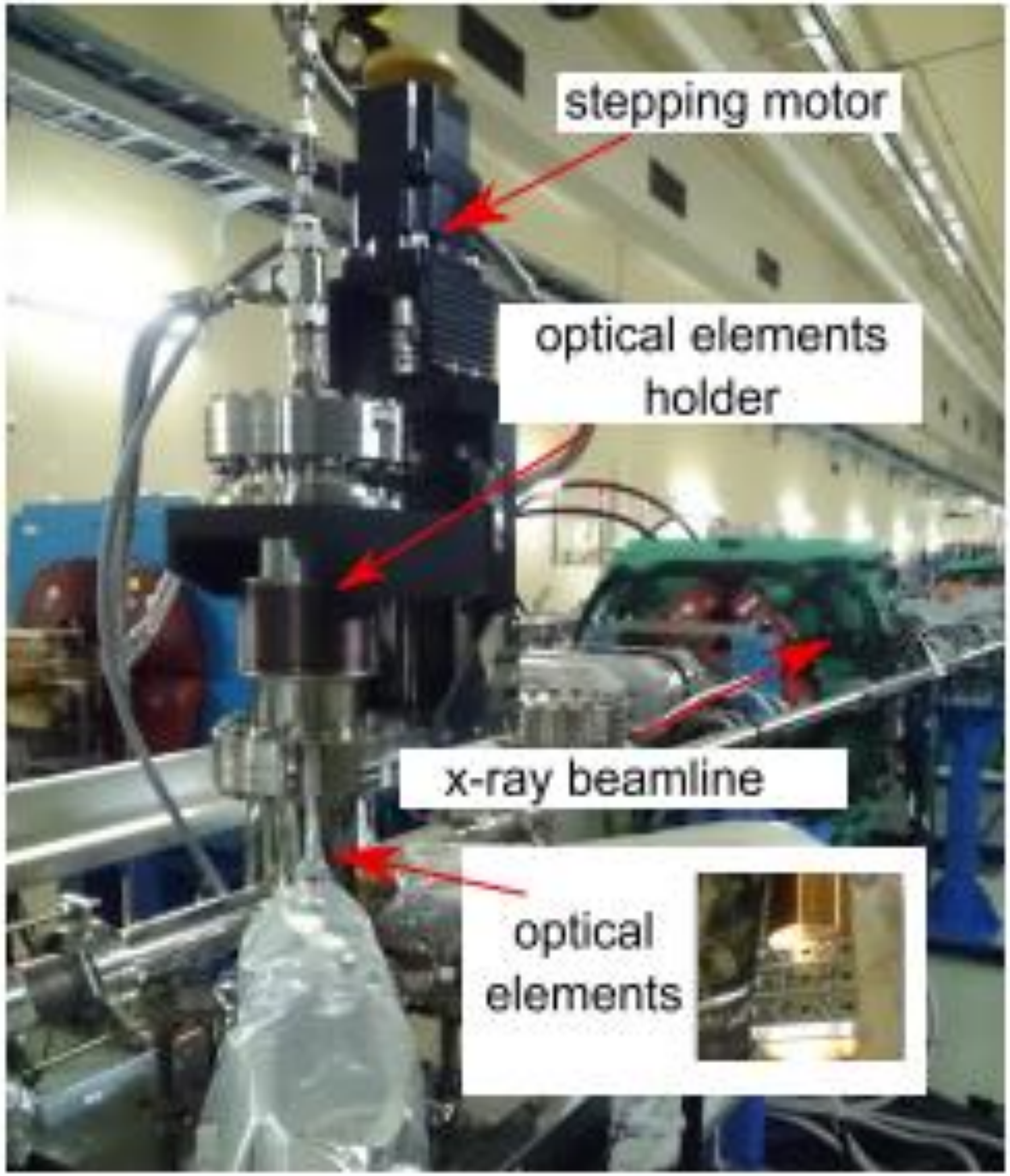
LER (Fuji straight section)



Source bending magnet

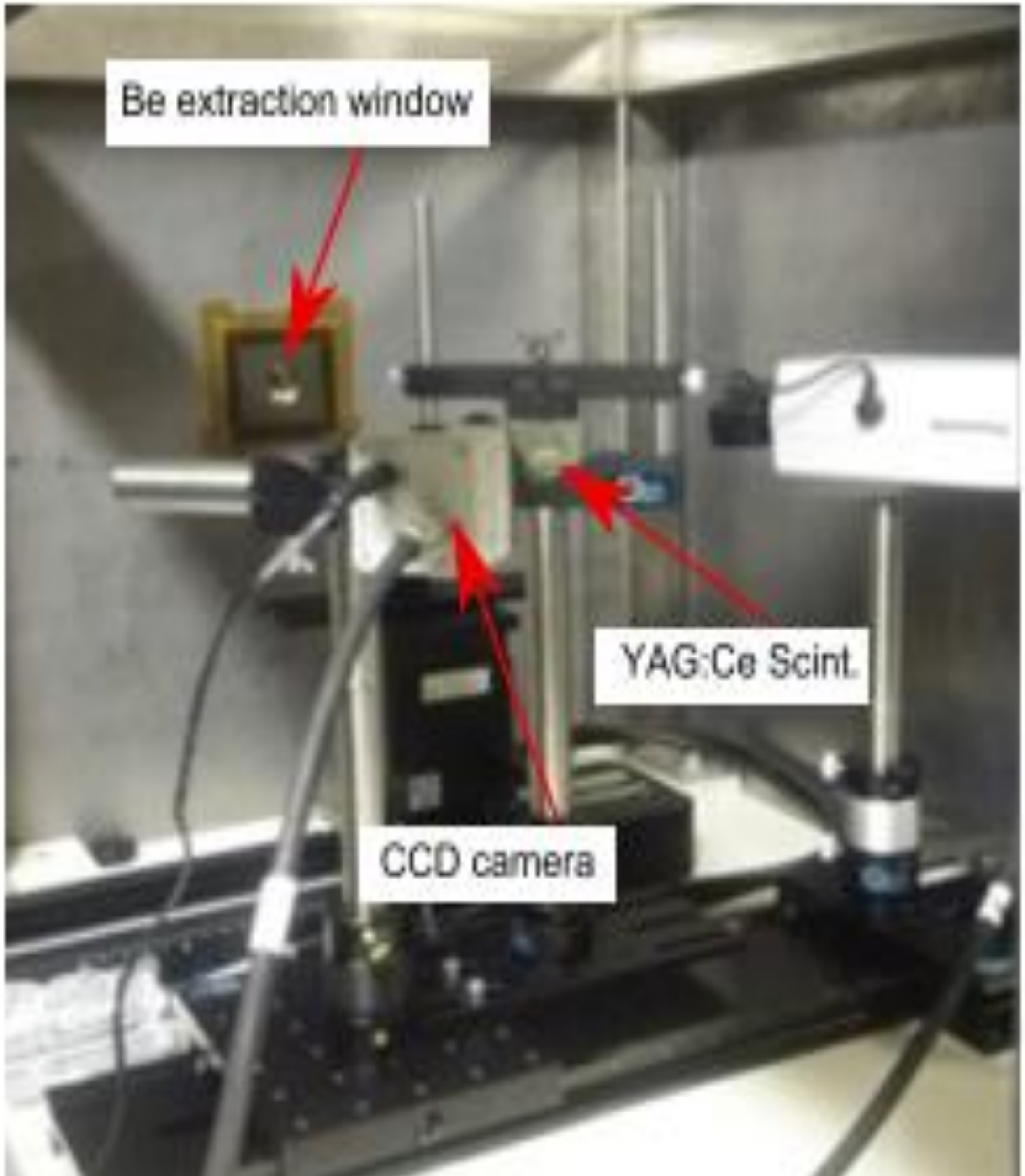
Extraction point of X-ray from vacuum duct




stepping motor
optical elements holder
x-ray beamline
optical elements

Downstream view of X-ray monitor line

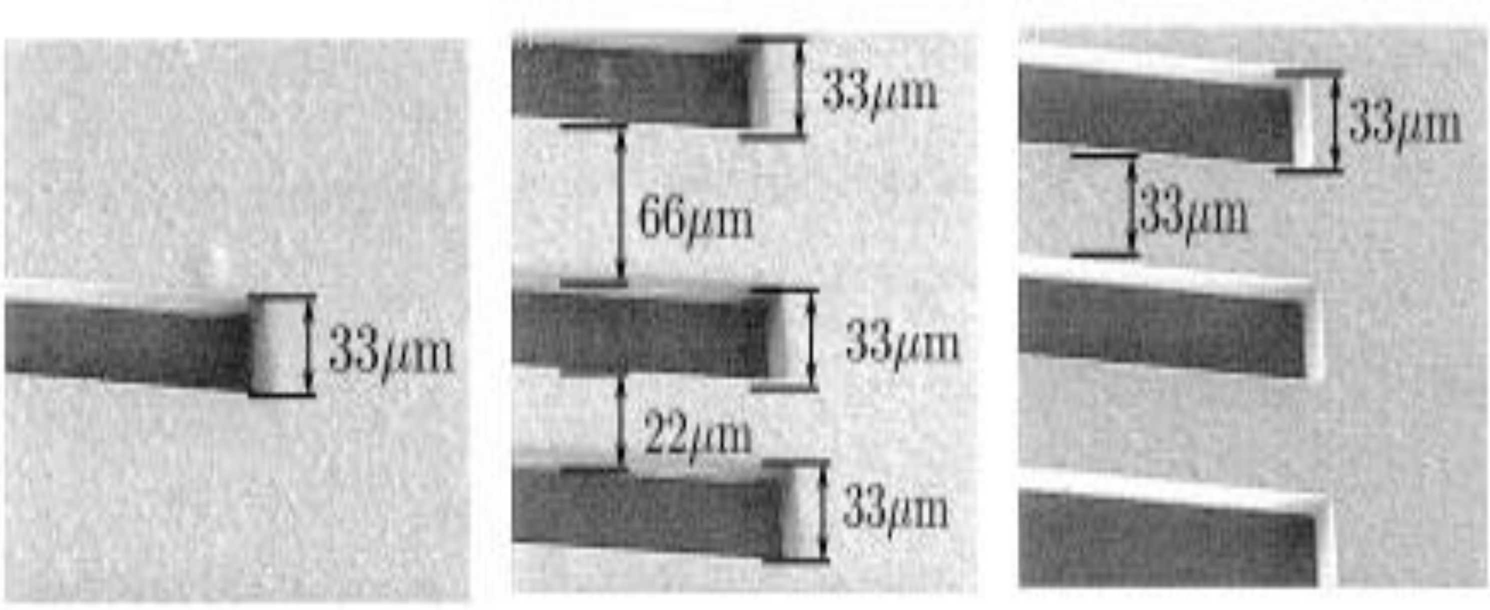

lead shielding
incoming x-ray
readout enclosure
water colling


Be extraction window
YAG:Ce Scint.
CCD camera

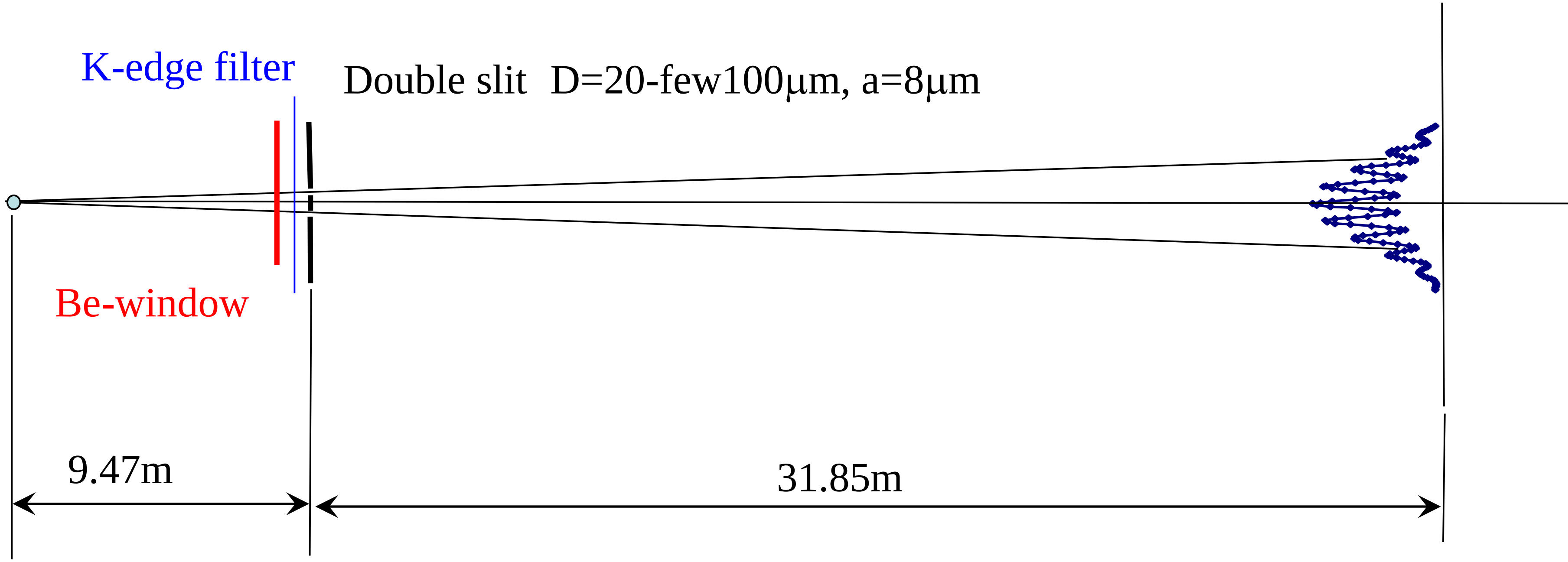
Making of Double slit with lithography of gold coating on Si base

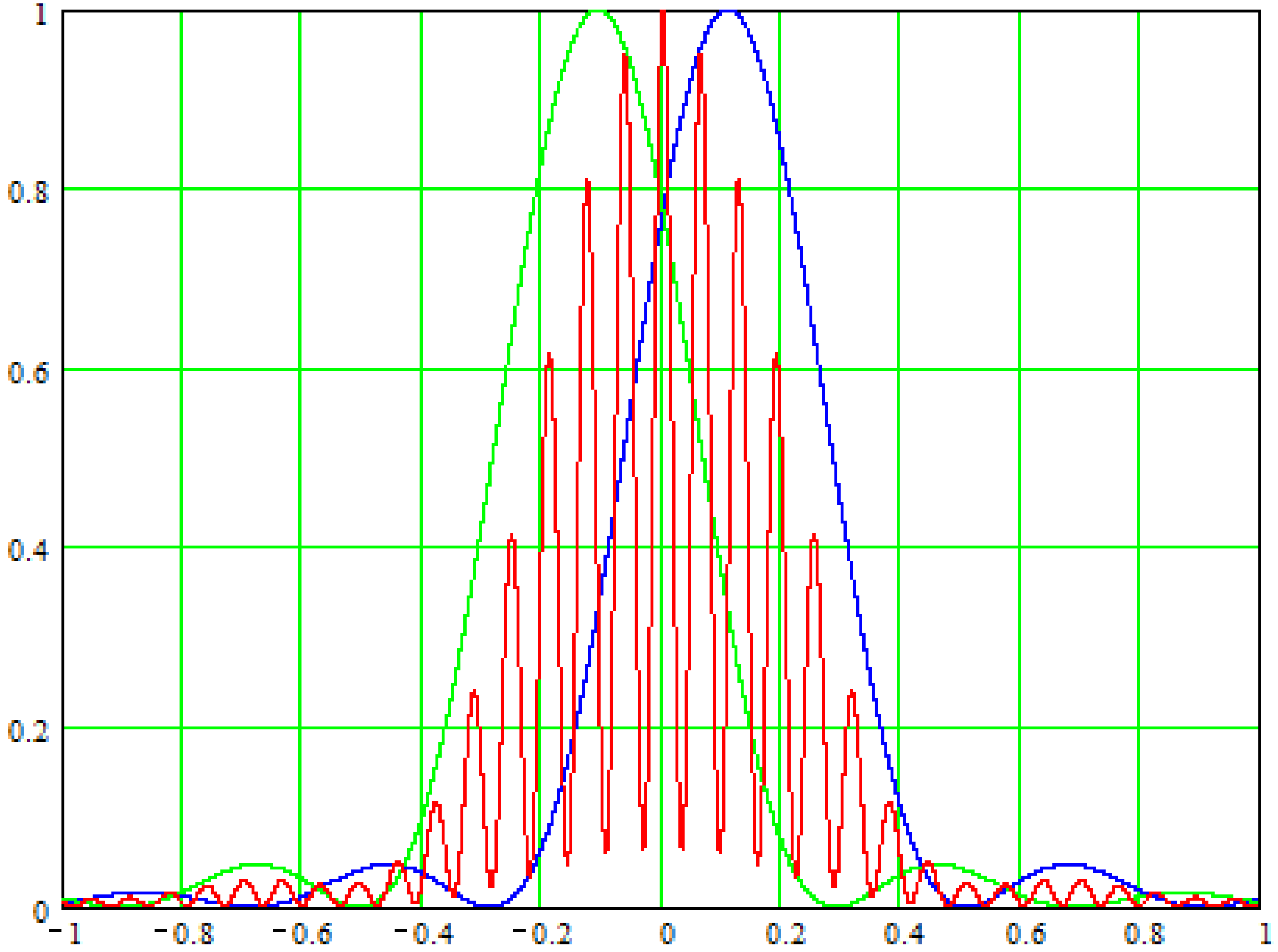
Very beautiful mask pattern for coded aperture with 20μm thickness Gold plate.

We can achieve the contrast better than *<u>two and half order</u>* with this mask.

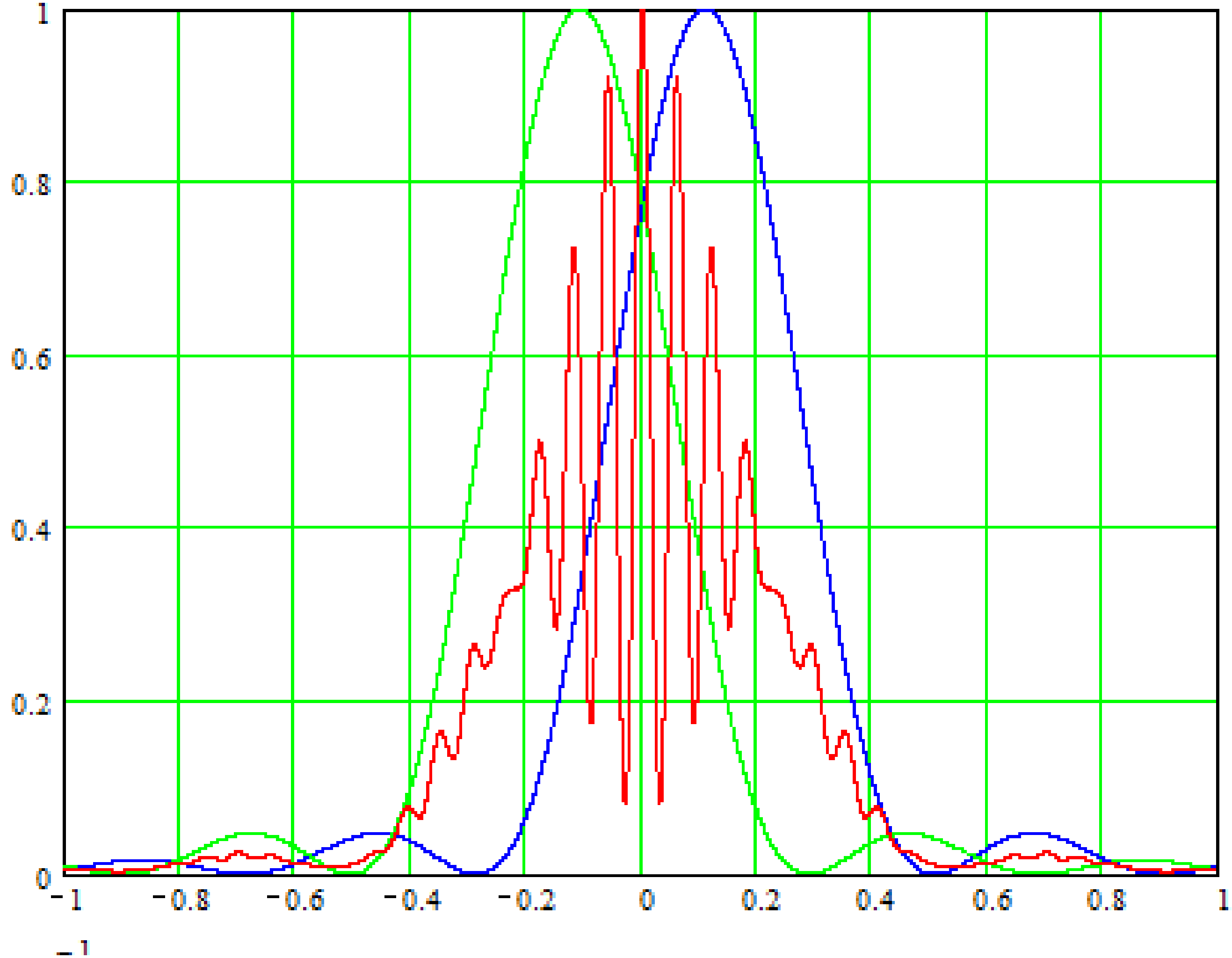


Possible configuration of X-ray interferometer at SuperKEKB





A calculated interferogram for SuperKEKB at 31.85m downstream from the double slit with monochromatic ray at 0.1nm. The double slit separation is 50μm, slit width with 8μm.



A calculated interferogram for SuperKEKB at 31.85m downstream from the double slit with K-edge filter at 0.1nm.

Summary for X-ray interferometer test in the SuperKEKB

We can test the performance of X-ray interferometer by using the X-ray monitor beamline in the SuperKEKB

All of equipments are already existing in X-ray monitor beamline except the double slit.

We need to make double slit.

We propose a test of the X-ray interferometer in X-ray monitor beamline at SuperKEKB with a simultaneous cross check with the X-ray coded aperture monitor and visible light interferometer.

Thank you very much for your attentions!