Novel multi-collimator using BP-1 glass and application for X-ray CCDs

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CCDs in X-ray Astronomy

current status of X-ray CCD capability

- Position resolution : 10μm
- Energy resolution : 2%
- Sensitive band : 0.3-10keV
- time resolution : msec

Suzaku 2005, Japan

Newton 1999

Chandra 1999

ASCA 1993,Japan

Standard focal plane detector with totally good performance

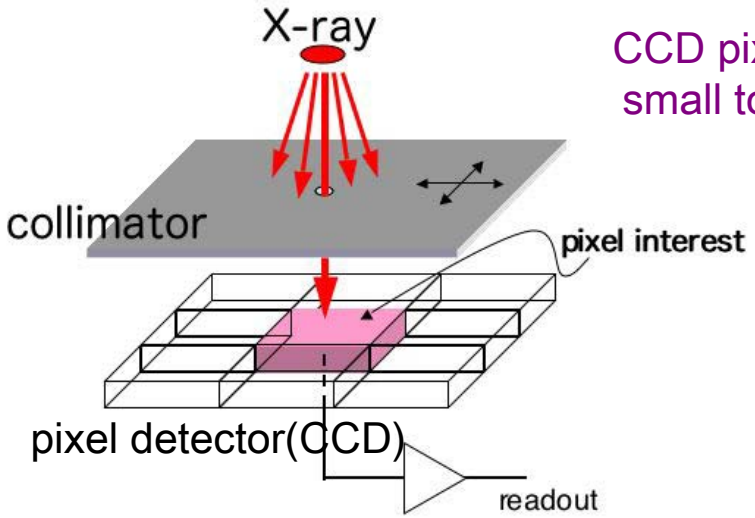
for the future mission

high efficiency above 10keV : now developed in Japan.

Important: investigation of the signal charge response

collimator scan v.s. mesh technique

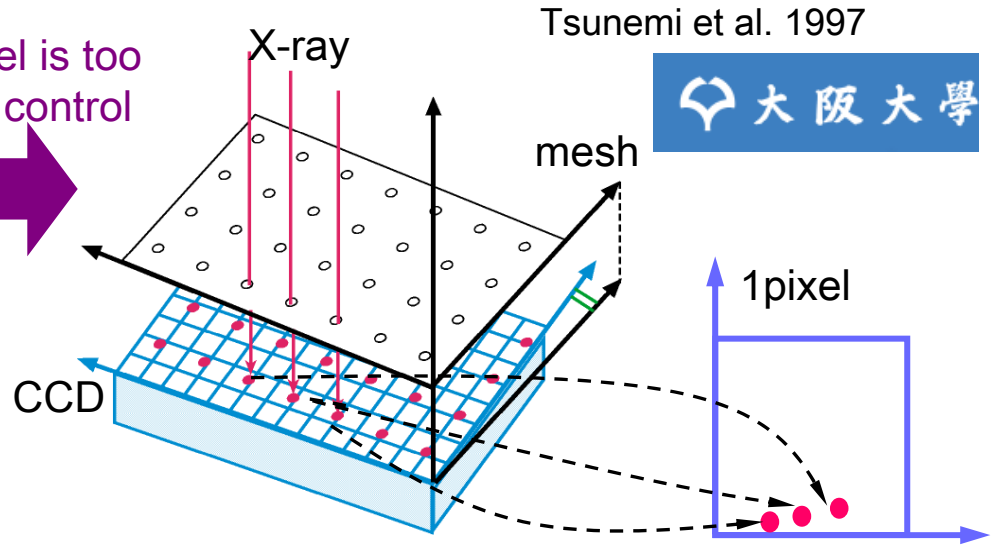
scanning with
mono-*collimator*



- X-ray absorber just above the detector
- one pinhole
- X-Y stage

CCD pixel is too small to control

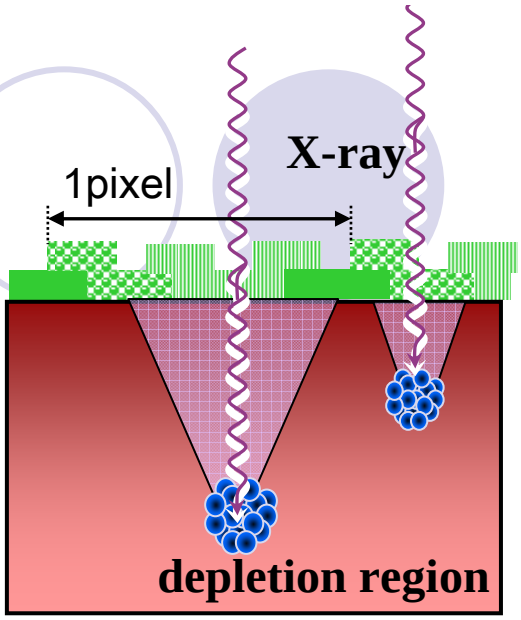
mesh-experiment
as* multi-*collimator



- Identical substructure of the pixel
- huge number of pixels
- huge number of pinholes

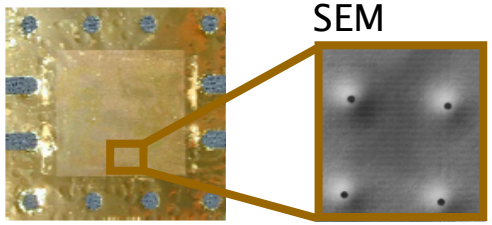
scanning over a pixel with μm order of accuracy.

The charge cloud shape



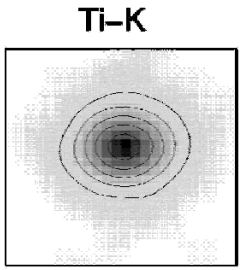
The results

- The unique practical technique:
  H.Tsunemi PSD5, E.Miyata PSD6
- measurement of the charge cloud shape:
  J.Hiraga et al. 1998 JJAP



(Optnics Precision co. ltd.)

material: Au
Thickness:13μm
hole size:2μmϕ
hole pitch:48μm



2-dim Gaussian
σ=1.5μm

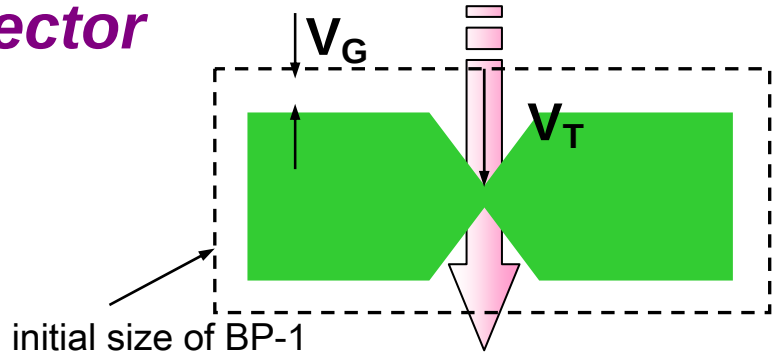
The problems

- Too thin to protect high energy X-rays.(<6keV)
- difficult thicker mesh with small holesize (high aspect ratio)
- not small enough of 2μm ϕ

How do we investigate for higher X-ray energies?

The BP-1 glass

irradiation of relativistic chargec particle



solid state nuclear track-etch detector

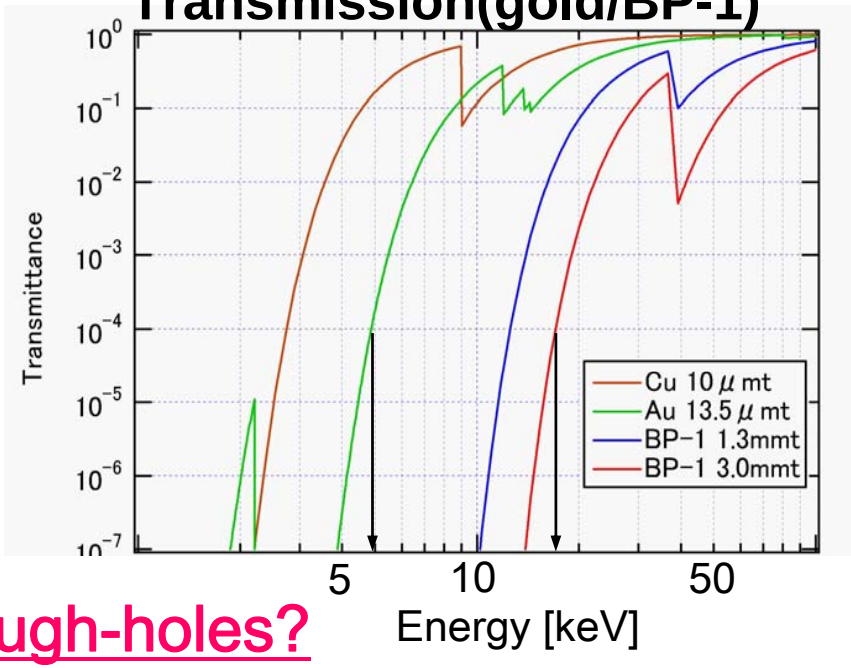
- high sensitivity ($s=V_T/V_G$)
- high detection threshold :Z/β >50 cone-shaped etchpit with chemical etching
- high-energy nuclear physics, cosmic-ray physics etc..

construction of BP-1[wt%]

O	Na	Si	P	Ca	Sr	Ba	total
42.2	1.39	1.06	29.0	0.003	0.045	26.3	100

S.C. Wang et al NIMB (1988)

- Low transmission up to 20keV
- glass --> easy to make it thick

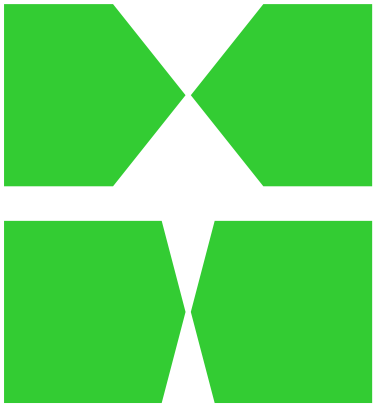


Can we product through-holes?

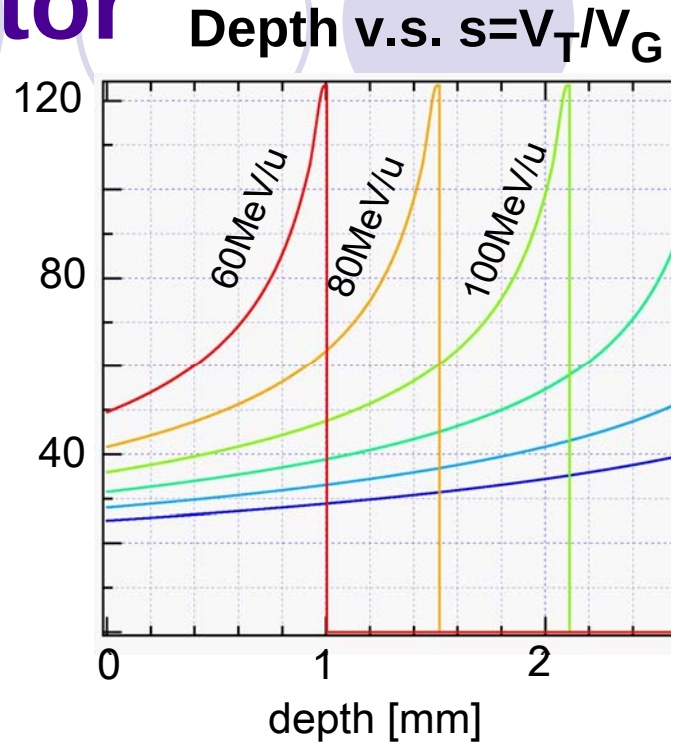
The novel multi-collimator

nano-*scale through-holes*

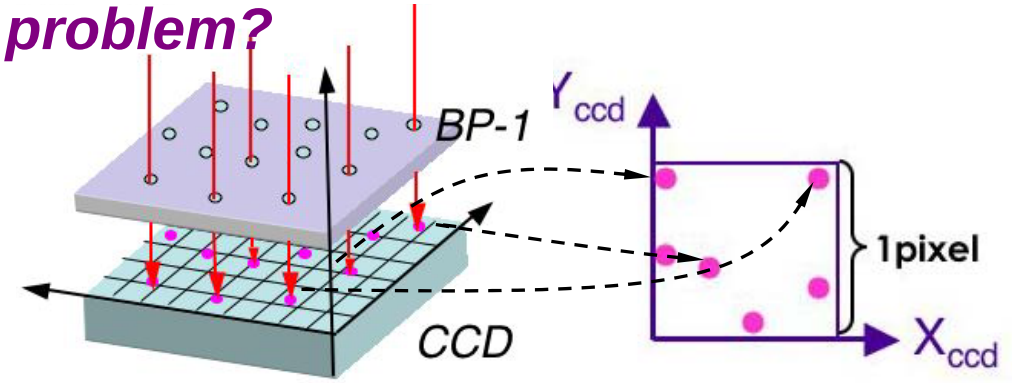
△ ○



- sensitivity: tighten the taper
- etching time: through hole
- initial track :~100nm



Does random distribution become problem?



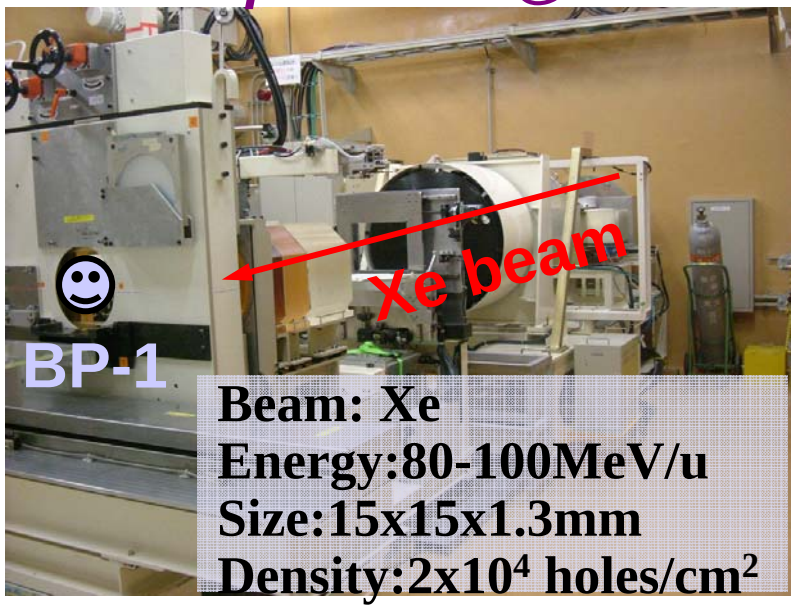
No!!

- alignment: pattern matching method
- scanning one pixel without move anything.

tiny through-holes & random sampling

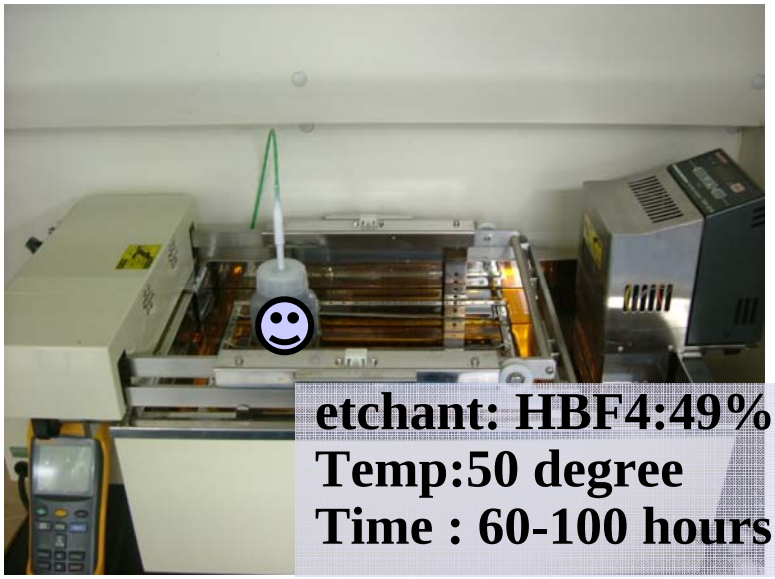
The first prototype

Beam experiment @HIMAC



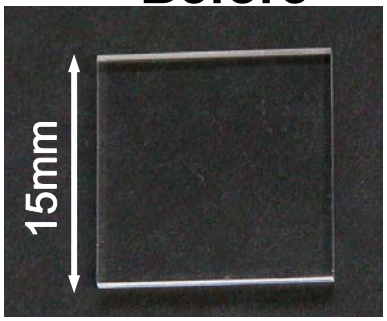
Beam: Xe
Energy:80-100MeV/u
Size:15x15x1.3mm
Density:$2x10^4$ holes/cm^2

Chemical Etching @KEK

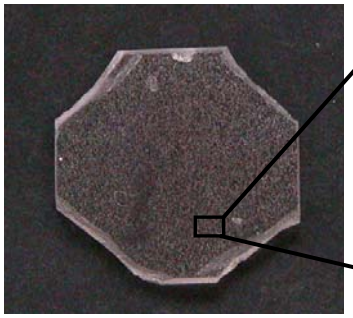


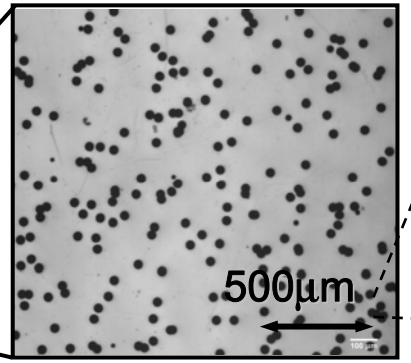
etchant: HBF4:49%
Temp:50 degree
Time : 60-100 hours

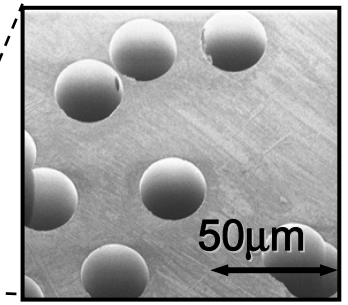
Before



After



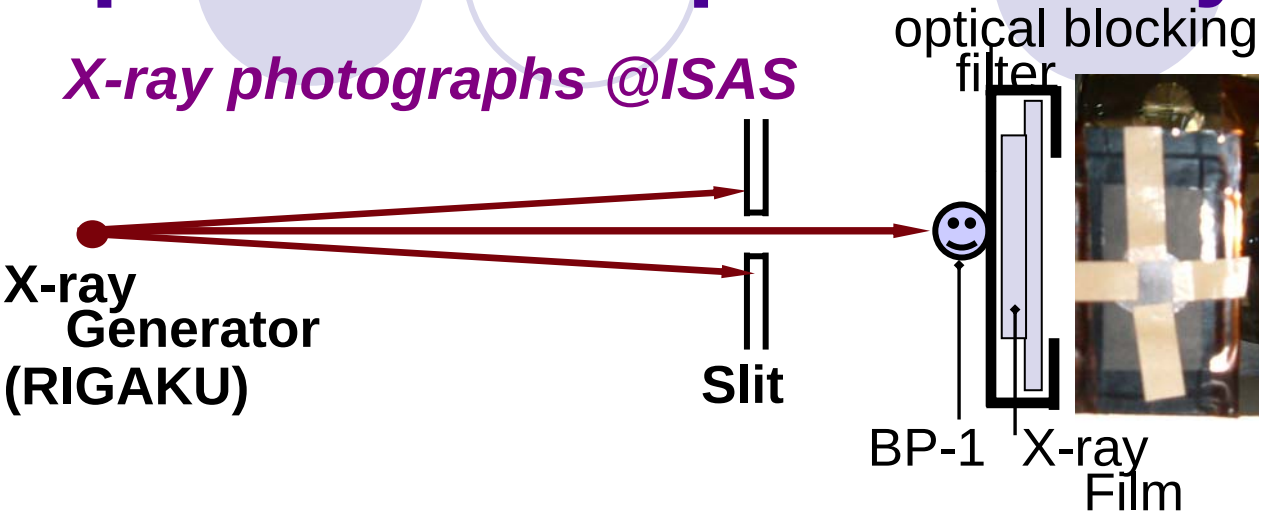




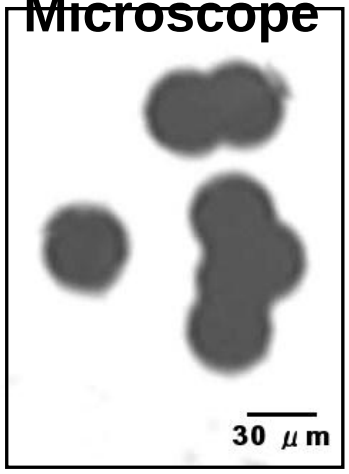
The first trial pieces have been produced successfully!

pin-hole shape for X-ray

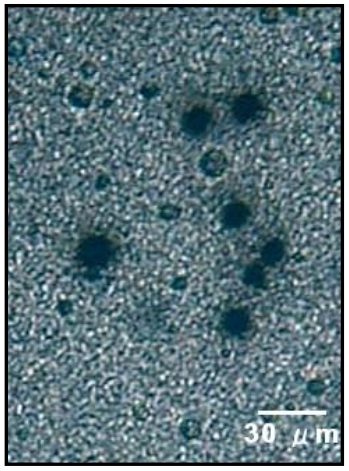
X-ray photographs @ISAS



Optical Microscope

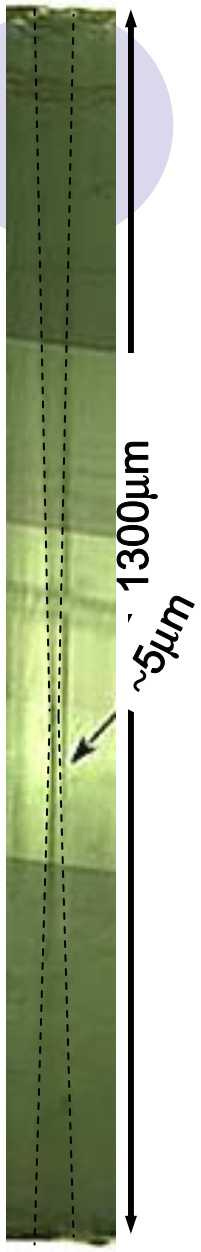


X-ray Film



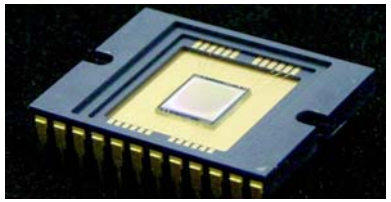
X-ray Energy :< 20keV
Beam length:36m
Film resolution:0.4μm

- same pattern
- X-ray photo:~6μmϕ
- surface:30μm
- inner:5-10μm

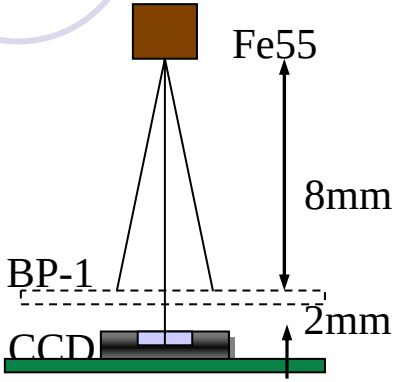


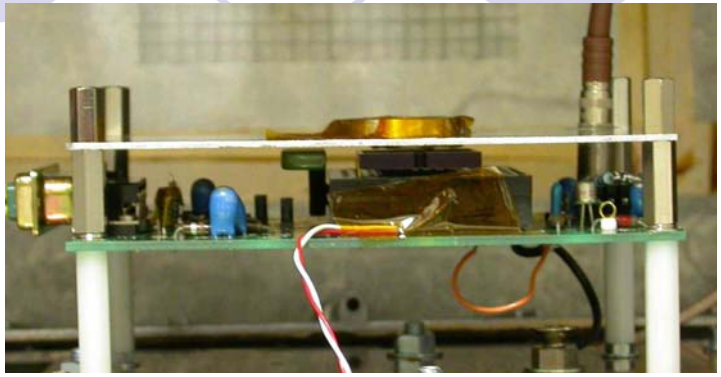
The BP-1 collimator functions well up to 20keV

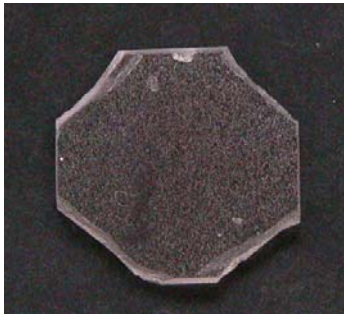
performance check with CCD



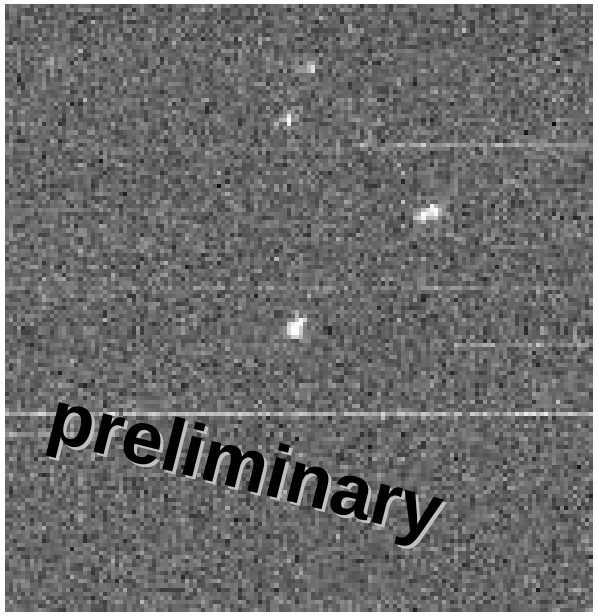
CCD :Hamamatsu
pixel#: 512×512
pixel size 12







BP-1 collimator
hole size 5μm /30μm
hole #: 10000 /cm²



CCD detection of X-ray through BP-1 collimator

summary and future work

- We have already established the mesh technique.
- Novel multi collimator using BP-1 glass are proposed.
  - Available X-ray energy: 20keV and higher
  - nano-scale hole size
  - easy handling
- The first prototype of the BP-1 collimator was produced.
  - BP-1:15mmx15mmx13mm^{t}
  - Xe:80-100MeV/u
  - 2x10^{4} holes/cm^{2}
- Hole diameter is still large:5μm(center), 30μm(surface)
- The first performance verification with X-ray Film was done.
- CCD detection test are ongoing with Fe55.

- CCD application with parallel X-ray beam
- Improvement of the performance of BP-1 collimator : smaller hole/thick glass

summary and future work