

## Pinhole X-ray Camera for PEP-II LER

6/27/03  
rev. 7/10/03  
J. Kadyk

### Items:

- Summary of Hobey's input parameters, calculations
- Present status of information gleaned re BESSYII (BII) via Mike Zisman and Karsten Holldack (email only).
- Information from discussions with Alan Fisher (SLAC), Fernando Sannibale, Dennis Baum (ALS at LBNL), Alex Lumpkin (APS at ANL), and Greg Stover (ALS, LBNL)
- Information about fast phosphors, from Steve Derenzo (LBL), Brent Wagner (GA Tech.), and the Web.
- Some design challenges

### Summarizing parameters and results from Hobey DeStaebler's May 9, '03 note:

#### Input parameters

##### Pinhole:

Pinhole diameter	.0012" = 30 $\mu$ m
Pinhole thickness	TBD (BESSYII has 150 $\mu$ m of tungsten)
Pinhole alignment	transverse necessary, and maybe angular
Source (beam) - pinhole	6 m
Pinhole - phosphor screen	20 m
Photon energy filter	>10 keV

##### LEB (positrons), at center of bend magnet:

Energy, E	3.109 GeV
No. bunches	1000 (guess)
Current, I	1.0 A (normalizing assumption)
$\beta_x$	35 m (guess)
$\beta_y$	35 m ( " )
Emittance, x	42.9 nm-rad [~ 30. : Mike Sullivan]
Emittance, y	1.5 nm-rad ["about right": M. S.]
Dipole field	7.52 kG
Dispersion x,y	?? [0.0 in x and y: M. S.]

#### Derived (calculated) quantities

##### Synchrotron Radiation (SR):

Radius of curvature	13.78 m	$[E(\text{GeV})/(0.3B(T))]$
Characteristic photon energy	4.84 keV	$[2.22E^3(\text{GeV})/\rho(\text{m})]$
Max. photon wavelength, $\lambda_{\text{min}}$	1.24 $\text{\AA}$	$[12,400/10 \text{ keV}]$
Fraction photons >10 keV	0.021	
Fraction energy >10 keV	0.19	[filter: included below?]
Ave. photon energy >10 keV	13.4 keV	

Optics, Source Size:

Magnification, source-screen	3.33	$[M_{x,y}=20 \text{ m}/6 \text{ m}]$
Pinhole subtended angle <sub>x,y</sub>	5.0 $\mu\text{rad}$	$[30 \mu\text{m}/6\text{m}]$
Source spatial, angular size		
$\sigma_x$	1225 $\mu\text{m}$	$[\sigma_x=\sqrt{(\epsilon_x\beta_x)}]$
$\sigma_y$	229 $\mu\text{m}$	$[\sigma_y=\sqrt{(\epsilon_y\beta_y)}]$
$\sigma'_x$	35 $\mu\text{rad}$	$[\sigma'_x=\sqrt{(\epsilon_x/\beta_x)}]$
$\sigma'_y$	6.5 $\mu\text{rad}$	$[\sigma'_y=\sqrt{(\epsilon_y/\beta_y)}]$
1.0 $\sigma_{x,y}$ source area	8.8E-7 $\text{m}^2$	$[\pi\sigma_x\sigma_y]$
2.0 $\sigma_{x,y}$ area at screen	3.9E-5 $\text{m}^2$	$[4\pi M_x M_y \sigma_x \sigma_y]$

No. of photons through pinhole:

SR emission, FWHM	164E-6 rad	$[1/\gamma, \gamma = E/m_e, m_e = 0.511 \text{ MeV}]$
SR, (ang. distr.) <sub>y</sub> , $\sigma$	69 $\mu\text{rad}$	$[??, 164 \text{ rad}/2.355]$
Angle of pinhole, $\alpha$	5.0 $\mu\text{rad}$	$[\alpha=30\text{E}-6 \text{ m}/6.0 \text{ m}]$
(Photons/e <sup>-</sup> ) <sub>x</sub>	3.2E-4	$[20.6E\alpha]$
(Photons/A-sec) <sub>x</sub>	2.03E15/A-s	$[3.2\text{E}-4*6.24\text{E}18\text{e}^-/\text{A-sec}]$
(fraction) <sub>y</sub>	0.0286	$[5\mu\text{rad}/(1/164\mu\text{rad}/2.355)(\sqrt{2\pi})]$
Photons thru pinhole	5.81E13/A-s	$[2.03\text{E}15*0.0286]$ (unfiltered?)

Flux, power at screen:

Fraction of photons > 10 keV :	0.021	
Fraction of energy > 10 keV:	0.19	
Ave. photon energy > 10 keV:	13.4 keV	
Bunch spacing, 1000 bunches:	7.33 ns	
Photon flux, screen	1.5E14/cm <sup>2</sup> -A-s	$[5.8\text{E}13/0.39 \text{ cm}^2]$ (unfiltered)
Photon flux, screen*	3.2E12/cm <sup>2</sup> -A-s	$[0.021(1.5\text{E}14)]$ (filtered>10keV)
Photon Power, " *	4.3E16eV/cm <sup>2</sup> -A-s	$[13.4 \text{ keV}*3.2\text{E}12]$ (filtered>10keV)
Power/bunch crossing*	3.1E8 eV	$[4.3\text{E}16*7.33, 1000 \text{ bunches}]$

[\*JAK numbers]

Resolution: diffraction and geometry:

a: From pinhole size, w	$[a = (w/\sqrt{12})*(26\text{m}/6\text{m})]$
b: From diffraction, $\lambda = 1.24 \text{ \AA}$	$b = [2.5\lambda/2\pi w(20\text{m})]$
Optimum resolution: 50 $\mu\text{m}$	$[\sqrt{(a^2 + b^2)}, \text{ with } a=b]$
Relative resolution: 6.6%	$[50(229)/(20/6)]$

Correction for "limb darkening" vertically:

Angular source width is not negligible relative to width of SR angular distribution.

Source subtended angle at pinhole	38 $\mu\text{rad}$	$[229\mu\text{m}/6.0\text{m}]$
SR vertical ang. distr., $\sigma_y$	69 $\mu\text{rad}$	$[164\mu\text{rad}/2.355]$
At $\sigma$ , relative intensity low by:	(1/1.16)	$[\exp(-0.5(38/69)^2)]$
Apparent width decrease factor	(1/1.14)	$[\sqrt{(1 + (38/69)^2)}]$

Single (or few) bunch selection?

Hobey has found on the Web a reference to a phosphor, Yttrium Aluminum Perovskite (or YAP), with ~40 ns decay time. The time between bunches at the LEB may be a few ns: 1000 bunches has been assumed above. However, the CDR shows 1658 populated plus 88 empty bunches, or a total of 1746, giving a bunch spacing of  $7.33 \mu\text{s}/1746 = 4.20 \text{ ns}$ . More information regarding fast phosphors has been found, and will be discussed later.

### Information Obtained Regarding SR Storage Rings

For the 4 rings investigated:

<u>SR Ring</u>	<u>Energy (GeV)</u>	<u>Current (mA)</u>
BESSYII (Berlin)	1.7	100
ALS (LBNL)	1.9	450, upgrade to 700
APS (Argonne)	7.	100
PEP/II/SLAC	3.1	up to 4000

The following is information from a variety of persons. Attached will be one file, which is a collection of abstracts of emails to me from these persons, and there may be useful information contained therein. These emails contained attachments, some of which are long, and so are referred to by title and file name, but are available on request.

SR storage rings of note are: ALS (LBNL), APS (ANL), BESSYII (Berlin), ESRF (ILL), NSLF (BNL), and SSRL (SLAC). PEP/II/SLAC is part of a HEP facility, but otherwise the same. I have only investigated the first three of these, and there may be much more to learn from the others.

#### BESSYII (K. Holldack)

As indicated in the email from Holldack, he has installed 3 pinhole arrays in the ring, which runs at 1.7 GeV, two on dipole magnets. A 16 keV filter (Mo) is used, and resolution of 10 - 20  $\mu\text{m}$  is achieved for size measurements (~ 1.  $\mu\text{m}$  in position). The mask is an array of 50 holes in 150  $\mu\text{m}$  thick tungsten, with 20  $\mu\text{m}$  diam. holes (larger on earlier models). The mask is sandwiched between copper plates that are water cooled, and have somewhat oversized holes aligned with the pinholes in the mask. About 3 watts of SR is absorbed here, with 100 mA circulating. The max. temperature rise is ~20 deg. and this deforms the pinholes only about 1.  $\mu\text{m}$ . We note, below, that Alex Lumpkin at ANL says he can detect a noticeable change in size measurement when temperature changes by a few tenths of a degree (who is right? - maybe both). The pattern is detected using a phosphor screen to emit in the visible, followed by a "frame grabber". It should be noted that the entire mask system is installed in the vacuum pipe of the ring.

#### ALS (Fernando Sannibale, LBNL)

This is a direct copy of the BESSYII pinhole array, but will be used at the ALS running at 1.9 GeV. The hardware now exists at LBL, and the installation is scheduled for late August (in case there is a desire to look at it, that should be done soon). Some pictures are available as a Web link (below), and a paper by Fernando (I have put these in the "Library" of documents). There is

a Power Point presentation that I can send separately (3.2 Mbytes) as well as other photos of the mask. The entire pinhole mask array, cooling, etc. is manufactured by a German company, FMB, and is available for only \$11,000 (recent cost). It was cautioned that for good resolution, the system up to the screen should be in a vacuum, though not necessarily the storage ring vacuum. It is interesting that there is no concern about leaks in the cooling system, even though there are several water tubes inside the main ring.

APS (Alex Lumpkin, Argonne National Laboratory)

This is the highest energy storage ring I've gotten information on, running at 7. GeV and 100 mA. The pinhole is indeed one pinhole, formed by movable blades, and so does not resemble the one at BESSYII. They are using a YAG/Ce crystal to convert the X-rays to visible light, then this is read out through an optical system and a CCD camera. The system is well described in a note that I will attach. It is a very precise system, apparently, being able to "detect submicron effects in a 100-micron beam size" (and detecting the Nov. 2002 earthquake in Alaska).

Comments:

Among the people I have contacted, there seems to be an agreement that we can achieve 10 - 20  $\mu\text{m}$  resolution with a X-ray pinhole camera. However, no one that I've discovered has tried to achieve this with selected-bunch imaging.

One of the most important criterion is the space available to install the pinhole camera system. As Alan Fisher has emphasized, space is quite limited; he suggested that we take a tour of the premises to help gauge how such a device might fit. It is not clear whether we could or should take advantage of the small cost, 11k\$, of the BESSYII system, available from the FMB company.

In terms of single, or few, bunch resolution, there appear to be very fast scintillators, with sub-nanosecond response. However, R&D will probably be involved in checking them out for this application. Several papers are included in the "Library", giving time response and luminosity. At LBL, Steve Derenzo and his group has been studying scintillators and phosphors for many years, and his work is very relevant to our requirements, I believe. Very recent discoveries include ZnO:Ga or ZnO:In, and CdS:In have decay times less than one ns (and rise times <100 ps); ZnO is said to be non-hygroscopic, and otherwise robust. The luminosity for the ZnO:In appears to be comparable to but somewhat less than a fast plastic scintillator giving about 10,000 photons/MeV response to charged particles.

Another link that may prove useful was given to me by Fernando: [www.proxitronic.de](http://www.proxitronic.de). This is a German company that produces a variety of optical equipment, and they have on this link a nice set of data on phosphors for X-ray work, including efficiency, spectral data, and decay times. However, fast phosphors do not seem to be in this list: the fastest seems to be 100 ns. This is probably because those with very fast response, and good luminosity, are generally recent discoveries.

Alex Lumpkin mentioned gated imaging devices, including gated microchannel plate/image intensifiers, that could resolve 200 ps intervals. He also mentioned using a streak camera, and

thought Alan Fisher would know about this. In this regard, Brent Wagner gave the name of Perry Bell, at LLNL, who has used very fast gated image intensifiers (microchannel plates).

At LBL, I have an X-ray generator with a Cu cathode that could be useful in checking response to X-rays: it has a discrete line at about 8 keV (it uses a "diffraction" X-ray tube), but can produce photons up to the HV supply limit of 20 keV (bremsstrahlung), and twice that if a 40 keV supply is provided. The max. current is 40 mA. There are a set of selectable metal filters for shaping the spectrum, plus an open hole for no filtering.

We will need to establish more precisely some of the input parameters, such as no. of bunches and x and y beta, dispersion (Mike Sullivan has supplied values for these now - 7/9/03). The space limitations, geometry of the vacuum pipe containing the apparatus, cooling, phosphor, whether to have an integrating plus a single bunch mode (as suggested by Fernando), light yield, aging, alignment and real-time adjustment, calibration, ... are some design items that come to mind. There is some experience in using pinhole cameras, but at smaller fluxes and power densities that are expected here.

I have made one copy of all of the documents I have collected, but have not tried to reproduce the 3.2 MB Power Point talk by Fernando - that is available via email if someone desires.

### Concerns:

Some specific concerns that I have are:

- How to cool the pinhole, or mask, given the moderate energy, 3.1 GeV, and very much higher current, up to 4 A. How much cooling is needed: a fraction of a degree (APS), or tens of degrees (ALS)?
- The intense radiation may saturate the phosphor, resulting in an incorrect width measurement, or the phosphor may age rapidly, or both. How can the X-ray flux level be adjusted to keep it in an appropriate operating range?
- Space requirements: this is coupled closely with the design, both optically and mechanically. Perhaps the pinhole will exist in a separate pipe and vacuum system.
- As mentioned earlier, Fernando Sannibale strongly recommends being able to do "integrated" measurements over the entire beam, even if there is the capability for measuring individual, selected bunches.
- How can design concepts be test-proven before a final design is adopted?

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### Excerpts from E-mail Messages

May 19, '03, from Mike Zisman, et. al.

John:

Below is the answer I got from John Byrd at the ALS.

--Mike

Hi Mike, Our diagnostic is currently a K-B mirror pair which focusses 1 keV photons onto a BGO crystal. We use this for all spot sizes. We are building a pinhole diagnostic which will be installed in the next year. A few of the beamlines have their own beam size diagnostic. I can't give you an exhaustive list offhand of pinholes at other rings. I assume you are referring to rings with diffraction limited beam sizes in the visible/UV. Our new design is based (i.e. Copied!) on the Bessy-II design which uses a pinhole array. It works at 12 (or 17 keV). Spear 3 is putting in a pinhole camera. Vertical beam size measurement is not trivial for picometer emittances. We can talk at more length if you like. Fernando Sannibale of the ALS ap group is doing the new design.

John:

Here is information from BESSY.

--Mike

----- Original Message -----

Subject: diagnostic ports BESSYII, pinholes

Date: Wed, 21 May 2003 14:41:11 +0200

From: "holldack" <holldack@bessy.de>

To: <mszisman@lbl.gov>

mike,

peter kuske forwarded me your mail.

I installed 3 pinhole cameras at BESSY II, 2 of them in our 2 diagnostic frontends on dipoles. They consist of thermally stabilized pinhole arrays at about 6 m to the source on a dipole. The detector is about 3-4 m further downstream and consists of a Mo-k-band filter which sets a bandpass at around 16 keV, and a high resolution phospor. The x-ray - visible converted spot is then imaged in visible by a coaxial VIS-zoom optics and automatically analyzed by a framgrabber with software channel access to the control system. The resolution is  $\sim 1\mu$  with respect to position and 10-20 $\mu$ m with respect to size. Vertical emittance resolution is  $\sim 1$ pmrad using beta functions (see tune map example in paper 2).

The system was copied by the SLS and recently also by LBL (fernando sannibale and denis baum). I gave them all the details. Tell me what details you need. Here, at first a more general paper at DIPAC and at the European epics meeting last year.

regards karsten.

.....  
Dr.Karsten Holldack

BESSY

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12489 Berlin

phone: +4930 6392 3170  
fax: +4930 6392 2990

Attachments: .....

DIPAC01.pdf:

REVIEW OF EMITTANCE AND STABILITY MONITORING USING  
SYNCHROTRON RADIATION MONITORS

K.Holldack, J.Feikes and W.B. Peatman, BESSY, Berlin, Germany

EPICS02holldack.pdf:

Photon Beam Diagnostics at BESSYII, Supervisor and user Controls, K.Holldack

June 12, from Dennis Baum (LBNL)

Subject: pictures of FMB diagnostic on arrival

Date: Thu, 12 Jun 2003 11:09:24 -0700

From: Dennis Baum <DJBaum@lbl.gov>

Organization: Lawrence Berkeley National Laboratory

To: John A Kadyk <JAKadyk@lbl.gov>

[http://www-eng.lbl.gov/~baum/OUTBOX/BL7/7.2\\_diagnostic/FMB/P0002130.JPG](http://www-eng.lbl.gov/~baum/OUTBOX/BL7/7.2_diagnostic/FMB/P0002130.JPG)

[http://www-eng.lbl.gov/~baum/OUTBOX/BL7/7.2\\_diagnostic/FMB/P0002128.JPG](http://www-eng.lbl.gov/~baum/OUTBOX/BL7/7.2_diagnostic/FMB/P0002128.JPG)

From Fernando Sannibale (LBNL), June 17, 2003

WPPB051.pdf

"A Second Beam-Diagnostic Beamline for the Advanced Light Source"

Subject: Emailing: PinHoleBladeAssembly.jpg,, PinHoleBladeAssembly2.jpg

Date: Tue, 17 Jun 2003 11:09:09 -0600

From: Fernando Sannibale <fsannibale@lbl.gov>

To: JAKadyk@lbl.gov

Your files are attached and ready to send with this message.

PinHoleBladeAssembly.jpg

PinHoleBladeAssembly2.jpg

WPPB051Poster.ppt

June 25, from Alex Lumpkin (ANL)

Subject: Re: X-ray pinhole camera Date: Wed, 25 Jun 2003 13:08:11 -0500

(CDT) From: "Alex H. Lumpkin" <lumpkin@aps.anl.gov> To:

jakadyk@lbl.gov CC: Lumpkin@aps.anl.gov, Bxyang@aps.anl.gov

Dear John, We indeed have an x-ray pinhole camera operating on a dipole source (S35 BM) in our 7 GeV storage ring. Our beam currents are typically 100 mA, but I suspect you will be running at higher beam currents. We water cool a power managing mask and the 4 independent

tungsten blades (9 m from the source) which provide a variable aperture. This is all in vacuum. The x rays transit a window and then are converted to visible light with a YAG:Ce crystal scintillator which has an 80-ns response time and are recorded by a CCD camera. We use an on-line video digitizer and process the data at a 30 Hz rate. We operate with about 22 micron system resolution with a 15 um X 15um aperture. You might find a faster scintillator, but it will probably have less light output. Still a MCP-intensified camera might detect a few bunches from the pulse train on one turn using a fast scintillator. Your beam sizes of 1200 um by 229 um seem very manageable, but your 1-2 A current is part of the challenge. I have referred you to my colleague Bingxin Yang's tutorial on imaging high-energy particle beams in the Beam Instrumentation Workshop proceedings of May 2002 at BNL (Greg Stover/LBNL should have a copy as well as the 2000 and 1994 proc. which have relevant articles). There are a few other relevant references at the end of his paper. We also had a paper in PAC'03 which describes sensing 1/2 micron relative beam size changes out of 40 um with the pinhole camera. Since I have that pdf file I attach it. I suspect we do have a great deal of info on x-ray pinhole cameras and time-resolved imaging here at APS and in the literature that you will find relevant to your task.

I also note that the BIW2000 Proc. from MIT has our article, "Recent Developments in Measurement and Tracking of the APS Storage Ring Beam Emittance", on page 622 that discusses some of the blade properties, temperature effects, ID gap effects, and other details. The first mask location is given. I noted you are aware of the ESRF design in Hobeys' note. Alex Lumpkin Photon Diagnostics Section Leader

Dr. Kadyk,

My name is Bingxin Yang and I work in APS. I read your note with interest, which summarized designs and capabilities of pinhole camera in several facilities quite nicely. If you do not mind, I would like to make some comments and share some operating experience with you.

(1) Pinhole / blade profile: At the APS storage ring, we use four independent blades for the x-ray slits (pinhole). The surface of the blades are ground cylindrical to avoid the angular misalignment. An x-ray pinhole, is really an x-ray tunnel, with 15 um opening, and almost 500 um length. In your case, with lower x-ray energy ( $E_c = 5$  keV), a thinner tungsten plate with larger opening, you may be able to add a small flare at both ends of the pinhole to avoid the need of angular alignment.

(2) One of the drawbacks of the independent-blade design is its sensitivity to the blade temperature. The blades and support structures are long, and 0.5 degree temperature change would move the tip by more than 0.5 micron, which is noticeable in the beam size tracking.

(3) One major consideration in the APS pinhole design, is the mechanical and thermal stability of the support / vacuum structure. Even

in the air-conditioned tunnel, the storage ring chamber moves at micron level as the temperature cycles at ~ 20 minutes intervals. What we end up doing is to mechanically decouple the pinhole and the detector from the ring chamber, and support them by specially designed stands. This depends a lot on machine operation requirements, whether one wants to know the relative position of the beam in the chamber or the floor. The APS is an user facility for people on the experimental floor, the machine manager decided that he wants to know the beam position relative to the user beamlines.

(4) Vacuum quality and carbon deposit: From the CO<sub>2</sub> emitted by the stainless steel vessel, carbon deposit on the components illuminated by synchrotron radiation seems to be unavoidable. It leaves the "beam footprint" after an extended period of operation. After five years of operation since our present pinhole camera installed, we have seen gradual reduction of intensity at the camera / scintillator. After the exercise of checking scintillator, cameras, filters etc., the final solution was the opening of the UHV system and scraping clean the small water-cooled masks (about 100 um) upstream of the pinhole, which was clotted by carbon deposit. I would like to have a pinhole array in the APS storage ring, but not sure how to deal with the carbon deposit problem on the small pinhole. If you could give me the e-mail of the person in BESSYII, I would like to learn from him how they solve the problem.

(5) Spatial and time resolution: Given the limited number of photons, saturation limit of the scintillator (plastic scintillators are worse), and the saturation limit of the camera pixels, the spatial and time resolution are linked. The "submicron" effect we claim at the APS is based on about 0.5 - 1 second averaging of images taken. When we used the gated intensifier cameras to study beam motion (at microsecond level, not ns level you are discussing), the accuracy of the beam size measurement is much compromised due to limited statistics. Since we could not do much about the number of photons emitted by the electron beam, finding a better scintillator and camera seems to be a way to go.

There are some other bits and pieces to talk about. We can continue later if you are interested.

Regard,            Bingxin Yang

[Mon, 30 Jun 2003. From: Bingxin Yang <bxyang@aps.anl.gov>, Alex Lumpkin <lumpkin@aps.anl.gov>]

Note (JAK): I have copied the three articles mentioned above, from BIW2002, BIW2000, and the Rev. Sci. Instr. article in Hobey's references on ESRF (Grenoble, France)

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## Phosphors

### **Summary of Phone contact with Brent Wagner, 7/1/03**

**J.A.K.**

The following are notes based upon a conversation with Brent Wagner, Senior Research Scientist at the Georgia Research Institute (GRI), Phosphor Technology Center of Excellence, as forwarded to him by Mike Harris, Chief of the Optoelectronics, Materials and Chemical Sciences Division at Georgia Tech, Atlanta, GA.

My email question of Mike Harris was:

We have a need for a very fast phosphor that will be excited by low energy X-rays, about 10 keV, and should emit in the visible, but the exact wavelength is not very important. This will be for tuning the e<sup>+</sup> ring at SLAC (Stanford Linear Accelerator Center) in the e<sup>+</sup>e<sup>-</sup> collider PEP-II. We would like to have a phosphor with decay times of a few nanoseconds; the incident radiation is synchrotron radiation from a bending magnet, and has, therefore, a very broad spectrum. Do you know of any such phosphors?

This email was forwarded to Brent Wagner, who was helpful on the phone and promised to forward additional material (which I have not yet received). Some relevant pieces of information from him I have collected below:

- Several other groups are interested in fast phosphors, including Bechtel (Las Vegas?), and LLNL (?).
- At LLNL, Perry Bell has done on very fast gated image intensifiers/microchannel plates, and probably at time scales of interest for our application.
- There are certainly a number of phosphors that should be responsive to X-rays in our energy range, with decay times as short as 200 ps. Cerium-doped Yttrium Silicate has a 10 ns decay, but there are several other possibilities.
- Another possibility is gadolinium silicate/Ce. As can be deduced, the Ce is the necessary ingredient for photon emission.
- Other phosphors mentioned are: ZnO/Ga and CdS/In: I don't know the decay times [Yes, these are known, and are sub - nanosec].
- At the GRI, a low energy electron beam is used to excite the phosphors.
- The deposition can be done by a "screen print" (?), or the way photocathodes are put on PMTs: put the substrate (glass, plastic, ...) at the bottom of a bucket of water, and sprinkle the phosphor powder on the surface: I'm told the phosphor will drift down

and stick to the substrate in a uniform manner. Sometimes a vehicle such as water glass (sodium silicate) is used to suspend the powder and help it adhere.

- Today, Brent left a message for me about a paper published by Steve Derenzo and Bill Moses here at LBL, entitled 412 Inorganic Scintillators, that sounds very interesting: measurements were done using 20 keV SR, Brent says. I just tried to call each of those people, and could only leave a message. Tomorrow I will try harder. [I have subsequently found out much from Steve Derenzo - see papers in Library]
- I also tried to call Perry Bell, w/o success, but left a message.

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### Summary of Discussion with Steve Derenzo; Papers

- Recent work has led to discovery of very fast, sub-ns, phosphors/scintillators that have good luminosity, no afterglow, and good mechanical properties. A brief, but incomplete table of fastest phosphors is:

<u>Scintillator</u>	<u>Time Response (ns, fwhm)</u>	<u>Luminosity (BGO = 1.0)</u>
ZnO (Ga)	0.21	0.15
ZnO (In)	0.65	~ 1/2 fast plastic scintillator
CdS (In)	0.17	0.001

[Values at 295 deg. K, or about room temperature - very temp. dependent.]

- These can be made available either in powder form (easier) or as macroscopic crystals that can be grown (about 1 cm size).
- Steve and his group have worked in this area for years, have exposed their phosphors at storage ring light sources (the NSLS at BNL), and have even used their test devices to look at time structure of bunches in the storage ring (plastic scintillator).

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### Summary, etc.

- The biggest challenge may be to find space for the pinhole camera system.
- Perhaps the next biggest challenge may be to adequately cool the pinhole(s).
- Another possible problem might be the filtering of the X-ray flux to keep the power density on the phosphor screen within the proper range, and still not lose resolution seriously. This is, of course, also coupled with the cooling question.
- The fabrication and testing of screens must be accomplished.
- The method of fast optical readout needs investigation and design work.
- Some kind of prototype testing in a suitable beam seems advisable.