Si 888 in backscattering, an 8-beam case

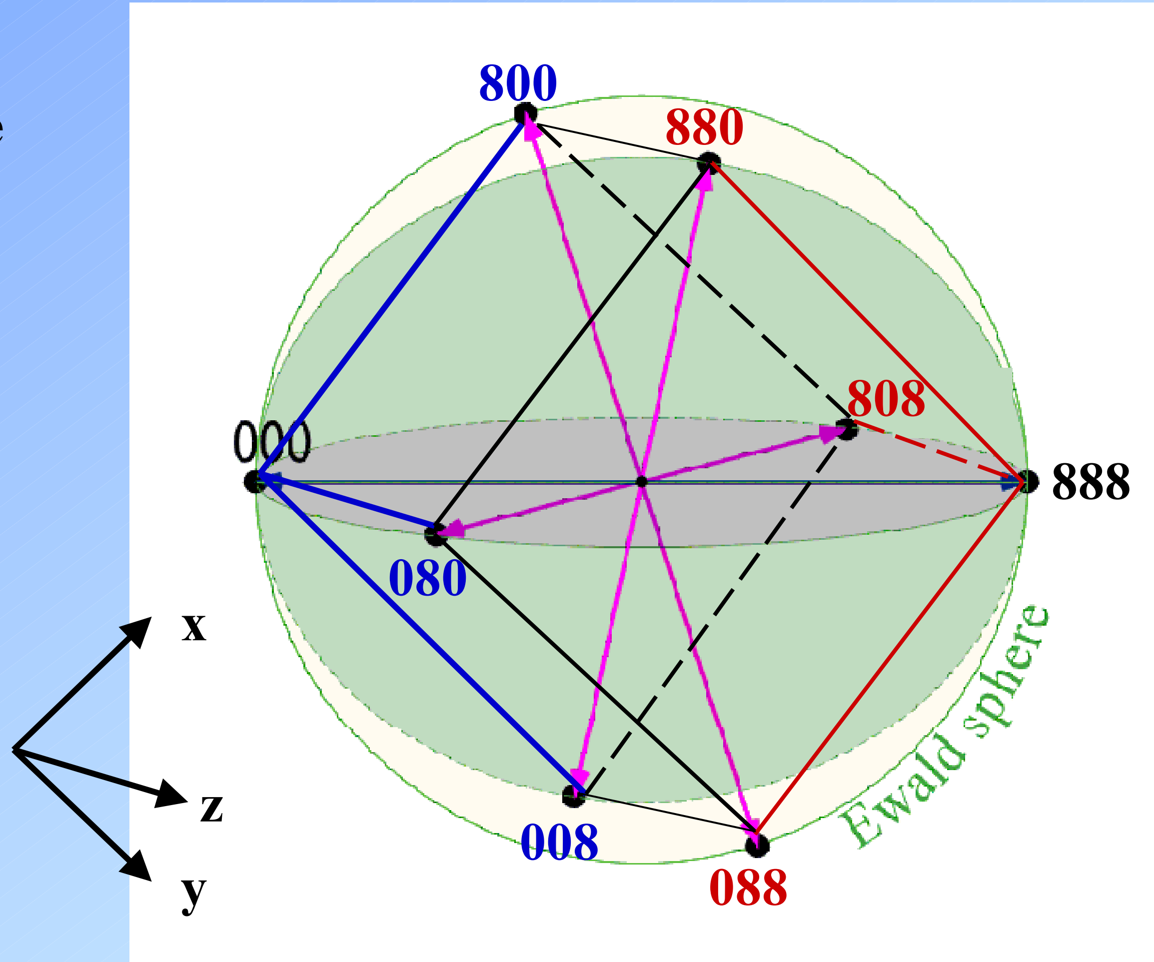
thesis Stefan Haubold

When a Si crystal (cubic) is oriented in exact backscattering for the 888 Bragg reflection, then there are simiItaneously further 6 reflections excited, i. e. a total a total of 8 reflections lie on the Ewald sphere

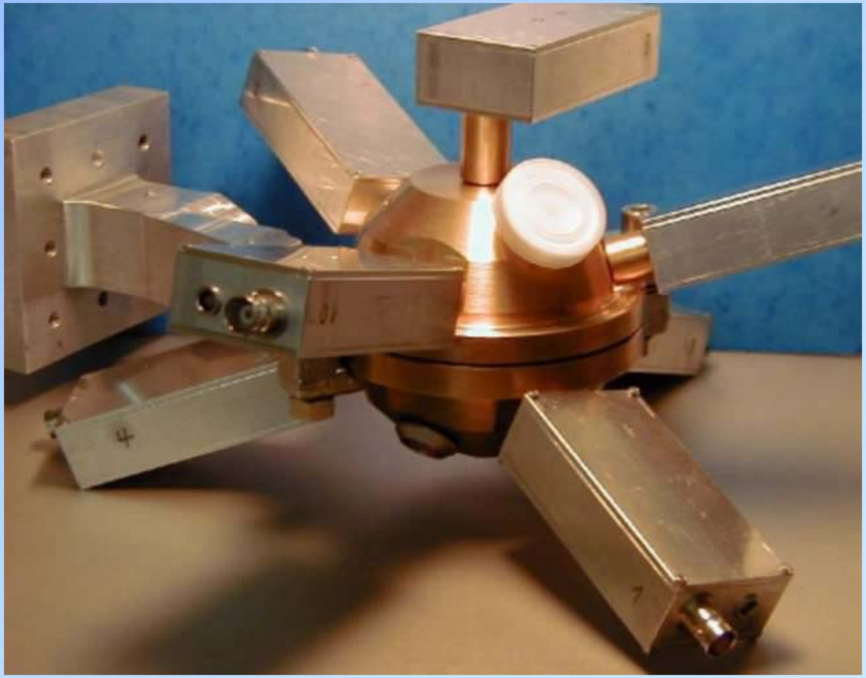
They are oriented along the corners of a cube

Laue direction:
000, 800, 080, 008

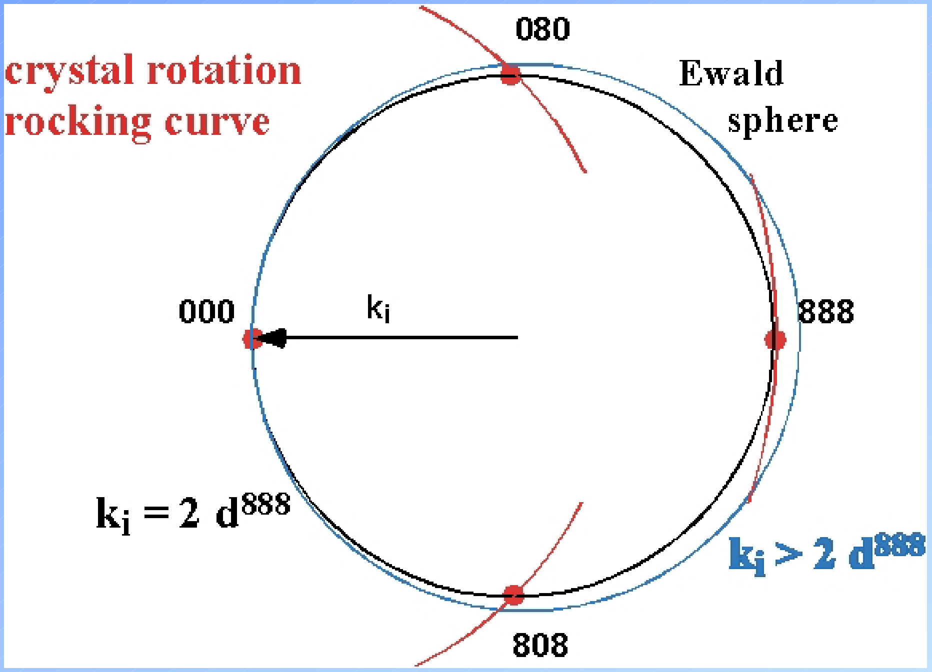
Bragg direction:
888,880, 088, 808

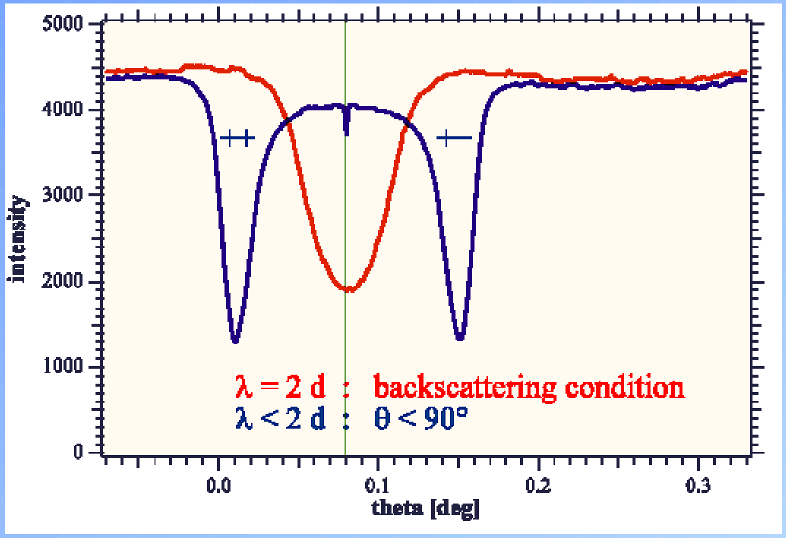


The sample / detector geometry

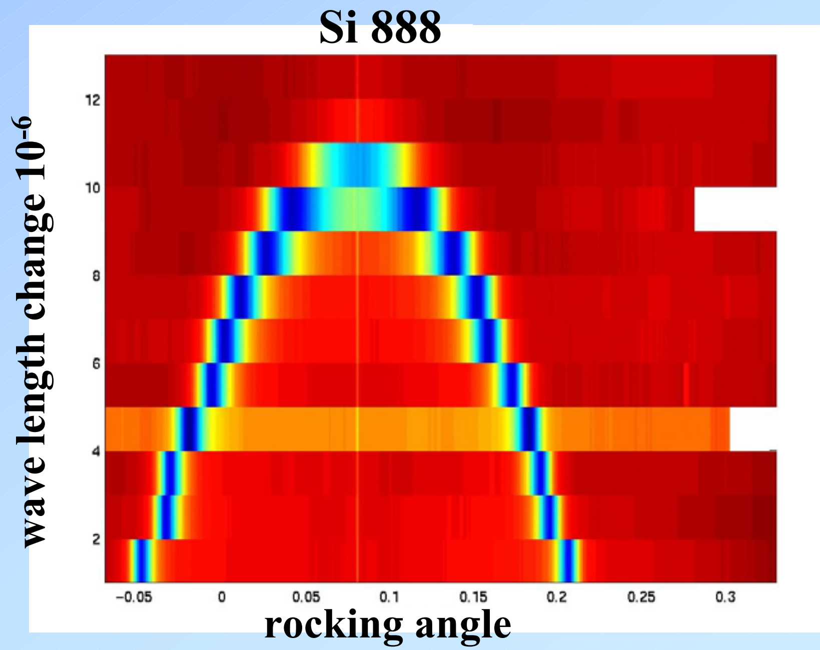


rocking curves near backscattering





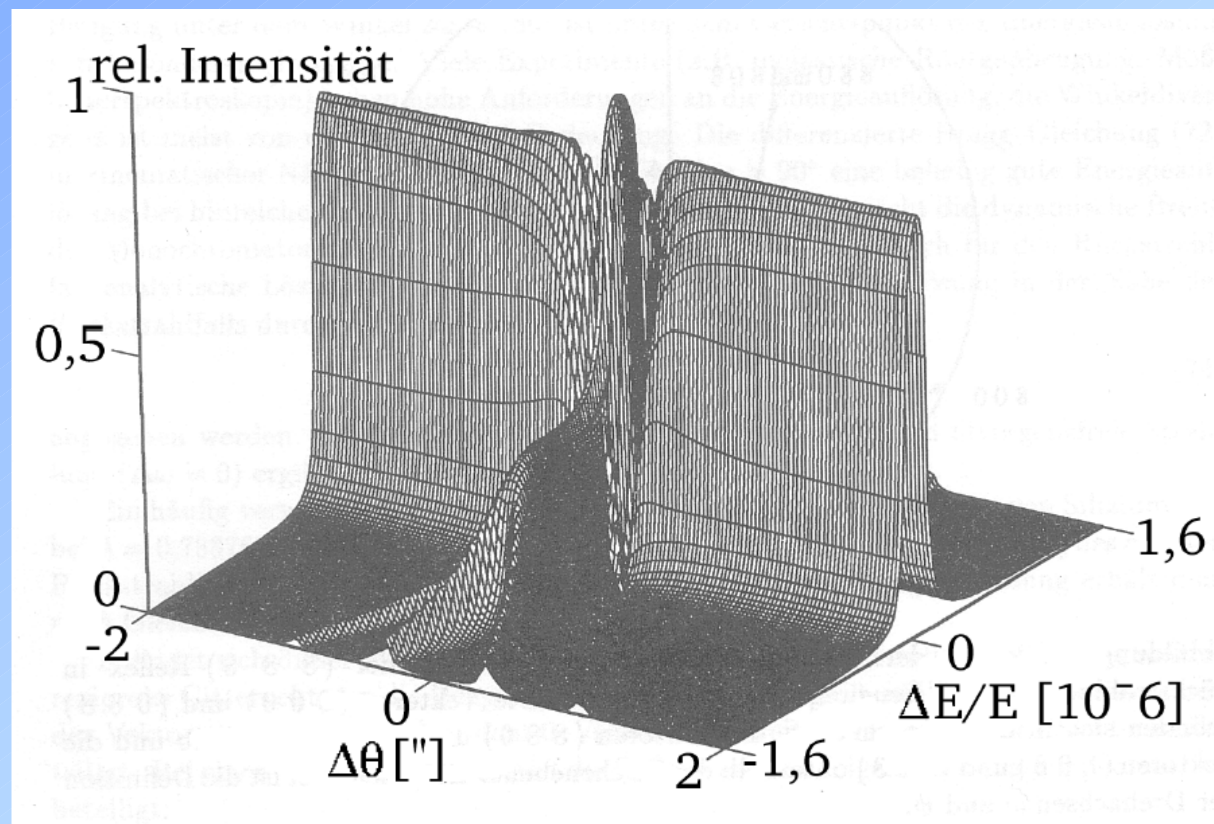
Approaching the exact backscattering condition



In reality the wave fields of all 8 reflections are expected to interact with each other, i. e. they exchange energy in a complex way

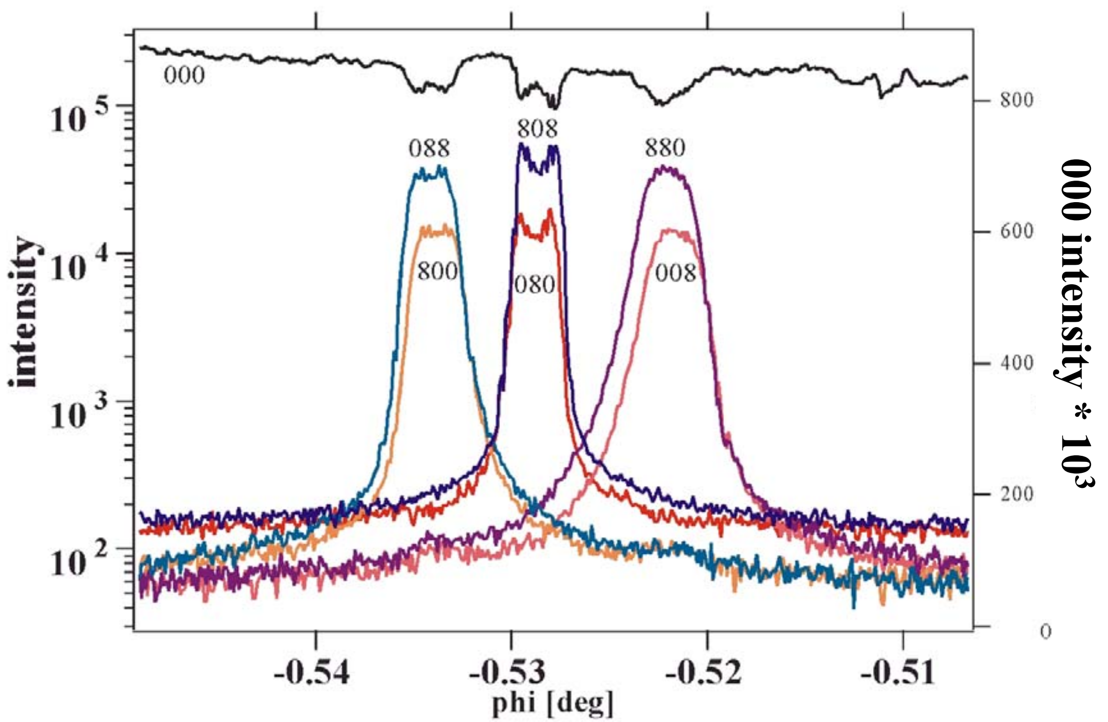
This complicates the intensity distribution

Is the back reflection peak strong in the presence of the other 7 reflections?



W. F. Schwegle,PhD thesis, Universität(TH) Karlsruhe, 1993

reflections close to the backscattering point



Results:

- all reflections are present
- Bragg geometry stronger than Laue geometry
- they exchange energy
- the calculated fine structure could not be verified likely due to 'coarse' beam divergence: source size too big to apply plane wave description
- # lower emittance source needed #

Photon storage in a crystal cavity

Nature, 2001

Storage of X-ray photons in a crystal resonator

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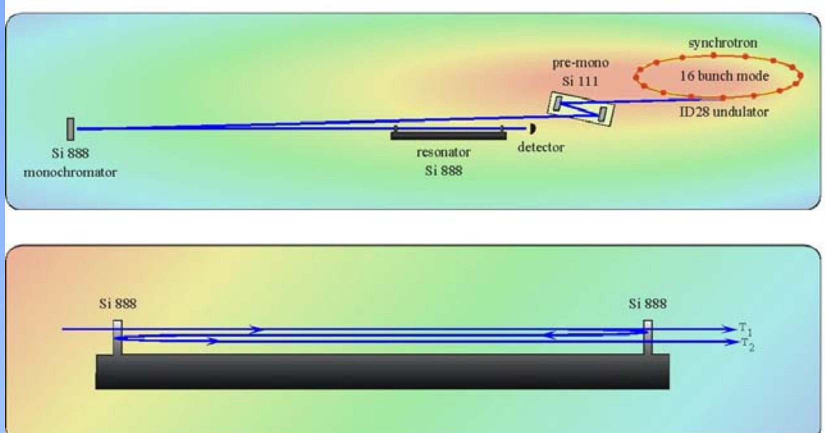
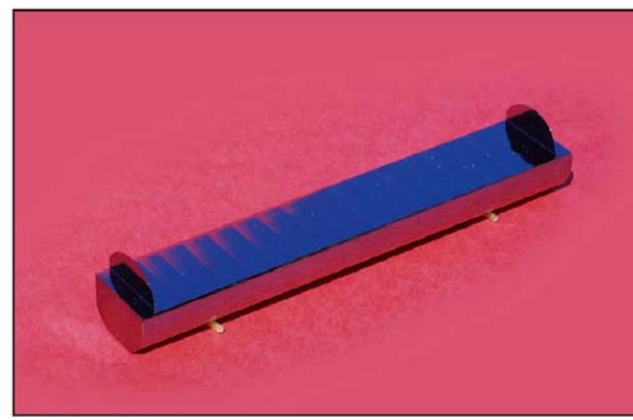
Can the Si 888 backreflection be used to store highly monoenergetic photons?

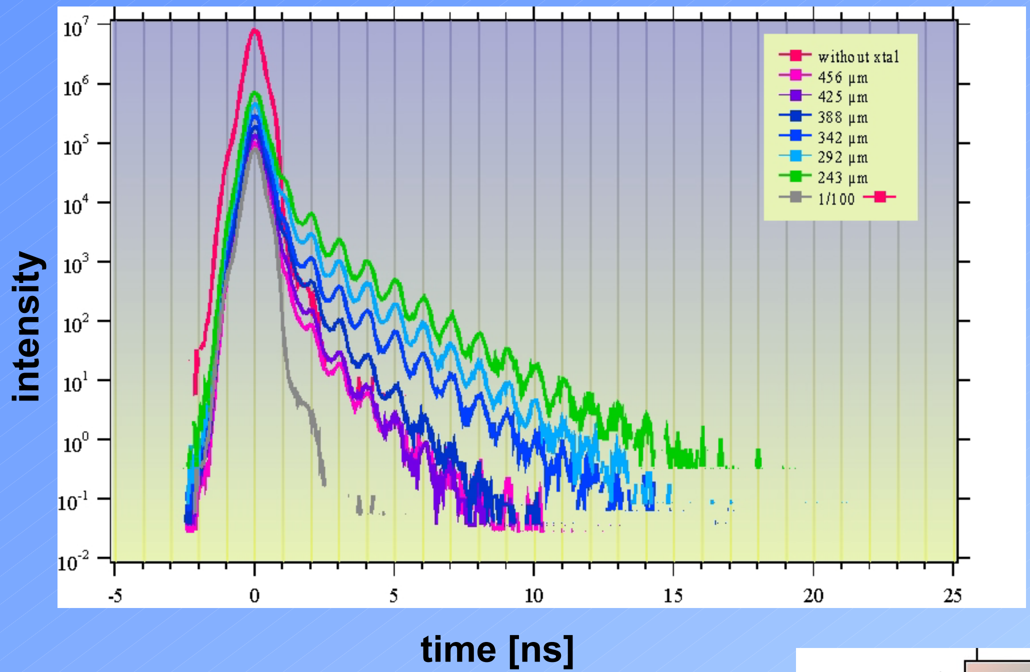
resonator setup



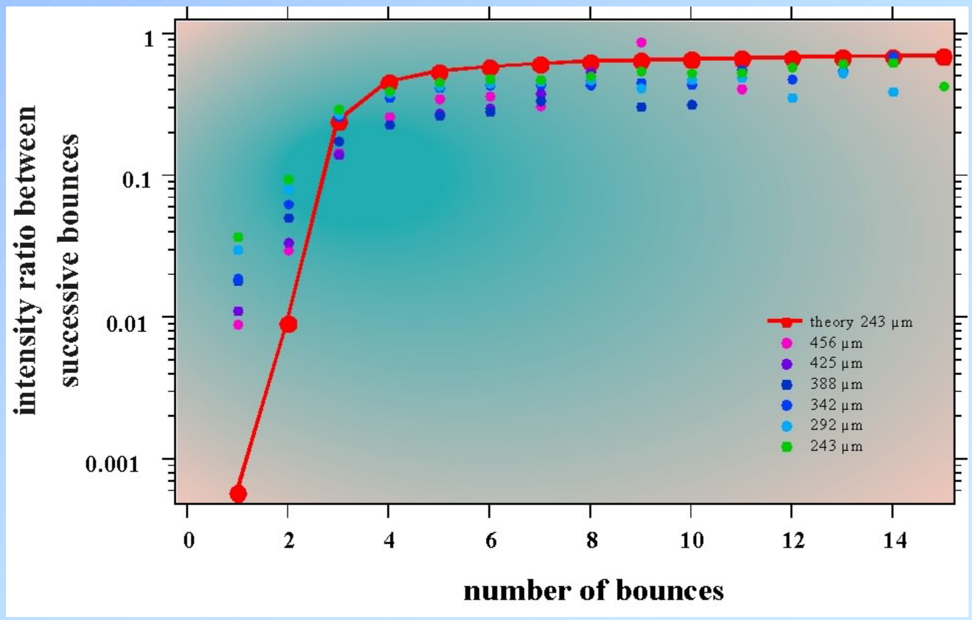
monolythic crystal cavity



15 cm



intensity
time [ns]
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
-5
0
5
10
15
20
25
without xtal
456 µm
425 µm
388 µm
342 µm
292 µm
243 µm
1/100



intensity ratio between successive bounces
number of bounces
1
0.1
0.01
0.001
0
2
4
6
8
10
12
14
theory 243 µm
456 µm
425 µm
388 µm
342 µm
292 µm
243 µm

Si 888 reflection:

X-ray energy:	**15.81648 keV**
energy resolution:	**$2.645 * 10^{-7}$**
Pendellösungs length	**148 μm**
absorption length	**490 μm**

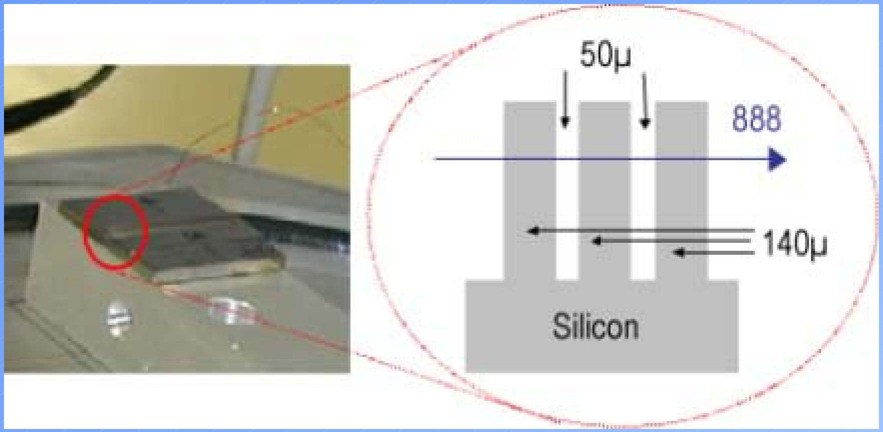
Results:

photons stored up to 15 bounces with more bounces with thinner crystals
high intensity ratio between bounces
after initial reflections no further depletion of the intensity of the 888 reflection

Applications?

delay lines for x-rays
mirrors / resonators for x-rays

a next step: towards a Fabry-Perot interferometer thesis Michaela Mitschke

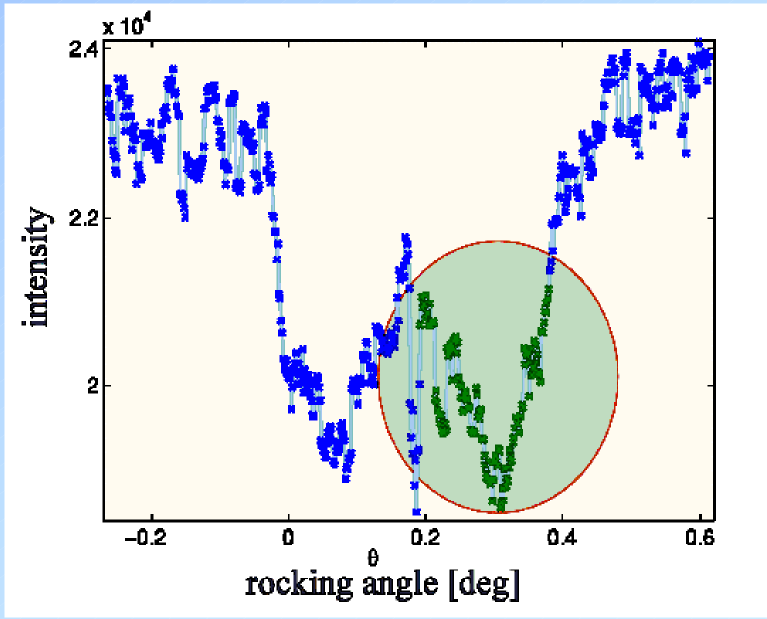


The gap between the crystal lamellae are reduced to less than the coherence length of 350μm on ID 28.

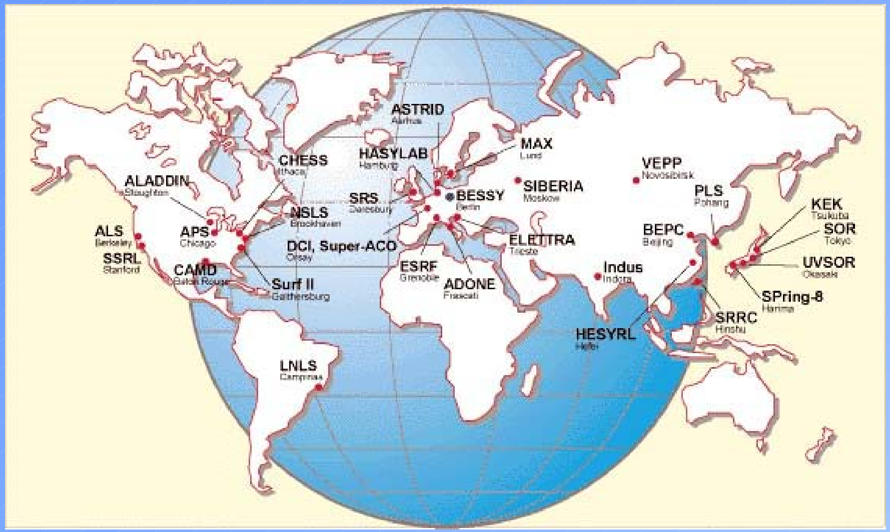
This provokes some fine structures in the rocking curves similar as expected for a Fabry Perot.

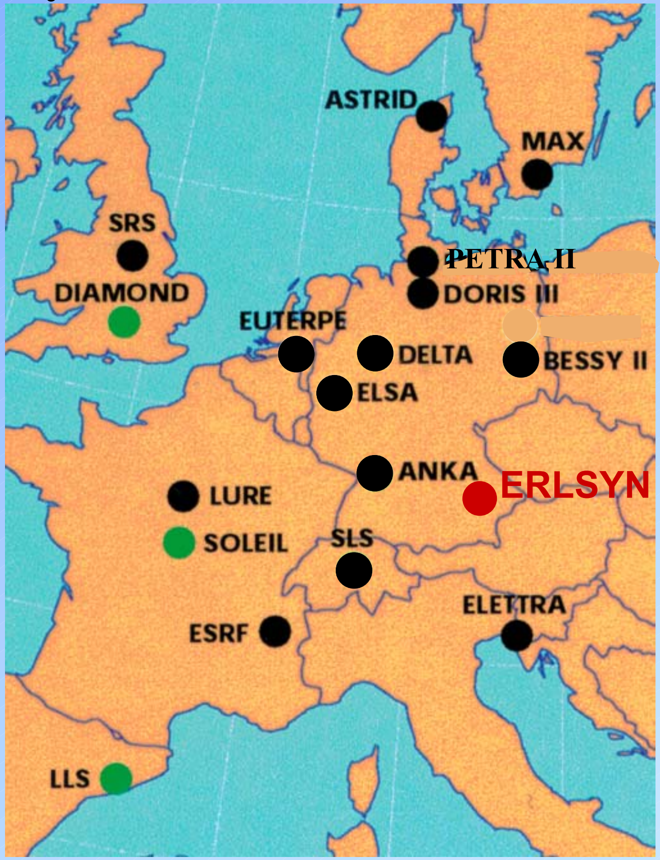
However this pattern was irreproducable likely due to insufficient stability of the beam and of the sample environment. Again the emittance is likely too big for a description within the plane wave theory.

Time-resolved measurements for such small structures?



The concept of ERLSYN: a SLS closely connected to universities





KFS: Komitee für Forschung mit Synchrotronstrahlung (2001):

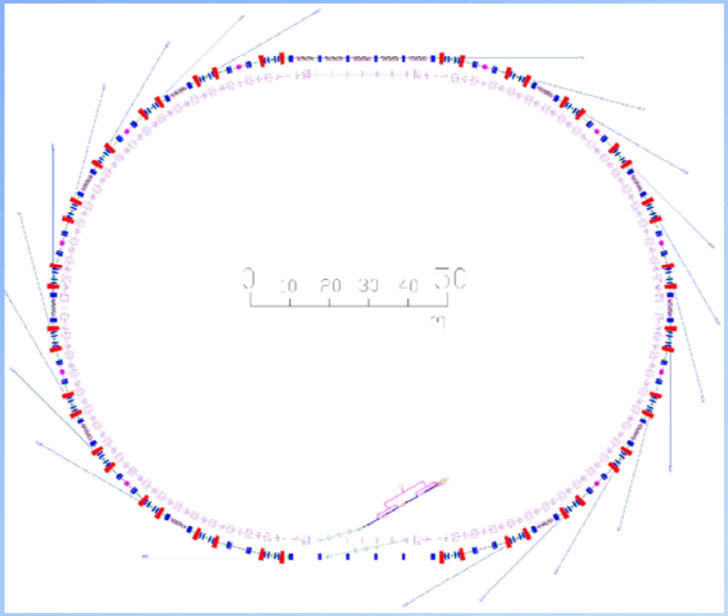
•‚A modern SLS is needed for the hard X-ray range‘
(soft X-ray are covered by BESSY II)

•‚ERL-sources are to be considered as the long term future of SLS‘

•The concept of ERLSYN acknowledges both recommendations and combines them into one project which calls first for the rapid construction of a modern storage ring source (phase I), which can be upgraded to an Energy Recovery Linac source (phase II)

Phase 1: storage ring source:

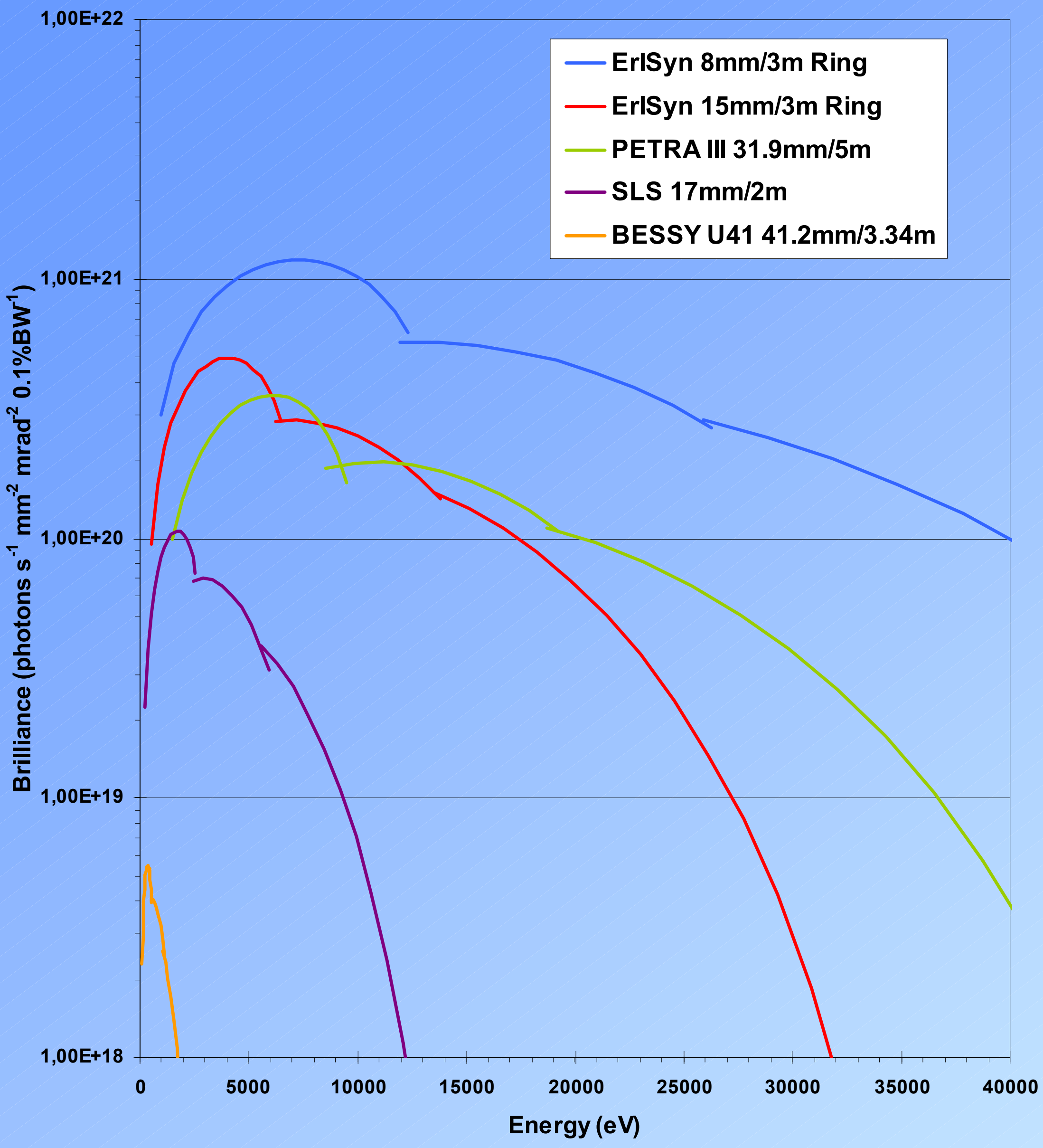
- 3,5 GeV storage ring
- 200 mA current
- top-up mode
- race track with two 30 m straight sections and with a circumference of 450 m
- different geometries have been studied with the Budker institute in Novosibirsk: 24/32 cell DBA, 24/32 cell TBA, with superbends and combined function magnets
- present proposal calls for a 32-cell-structure with ~30 insertion devices
- low emittance (1.6 nm*rad)
- narrow gap ID
- first light in 2007 for 200 M€



Beam emittance for various sources

source	energy [GeV]	circumference [m]	emittance [nm rad]
ERLSYN (without damping wigglers)	3,5	~450	1,6
PETRA-III (with 100 m damping wiggler)	6	2304	1
PETRA-III (without damping wiggler)	*6*	*2304*	*4,4*
Diamond	3	560	2,5
ESRF	6	844	3,9
SLS	2,4	288	4,4
SPring8	8	1436	5,9
BESSY II	1,9	240	6,0
ELETTRA	2,4	259	7,0
ANKA	2,5	110	41
DORIS-IV	4,5	288	66

ERLSYN, a source of high standard



Undulator tuning curves:

blue: ERLSYN undulator λ_u = 8 mm, length 3 m, current 200 mA

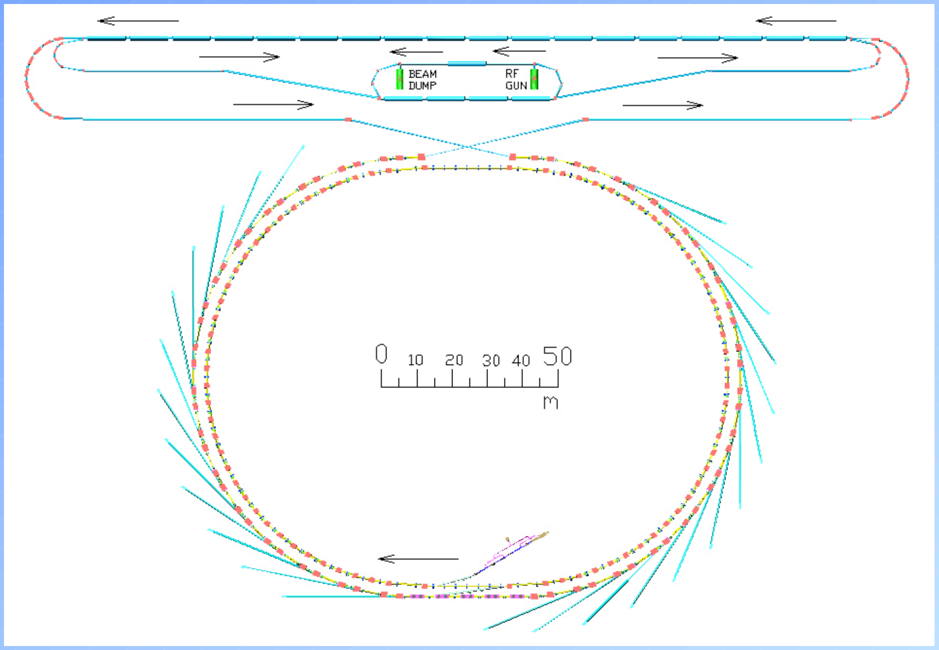
red: ERLSYN undulator λ_u = 15 mm, length 3 m, current 200 mA

green: U1-undulator at PETRA-III, λ_u = 32 mm, length 5 m, current 100 mA

violet: typical SLS-undulator with λ_u = 17 mm, length 2 m, current 400 mA

orange: U41-undulator BESSY-II with λ_u = 41 mm, length 3,3 m, current 250mA

Phase 2: ERL-upgrade:



Superconducting LINAC in three sections (28 →140 MeV, 140→700 MeV, 350→3500 MeV) delivers electron bunches which make one turn in the storage ring from stage I to deliver photons to the same instruments as in stage I

ERL parameters (I. V. Bazarov et al, APAC-2001)

beam current	**100**	***(10)***	**mA**
repetition rate	**$1{,}3 \cdot 10^9$**	**$1{,}3 \cdot 10^9$**	**Hz**

Promisses from ERL: reduced and isotropic emittance increased brilliance

source	energy [GeV]	circumference [m]	emittance [nm rad]
ERL high flux (10 mA)	3,5	~450	0,03
ERL high current (100 mA)	3,5	~450	0,2
ERLSYN (without damping wiggler)	3,5	~450	1,6
PETRA-III (with 100 m damping wiggler)	6	2304	1
PETRA-III (without damping wiggler)	*6*	*2304*	*4,4*
Diamond	3	560	2,5
ESRF	6	844	3,9
SLS	2,4	288	4,4
SPring8	8	1436	5,9
BESSY II	1,9	240	6,0
ELETTRA	2,4	259	7,0

isotropic emittance for focussing (nano beams), speckle spectroscopy, microscopy, etc.

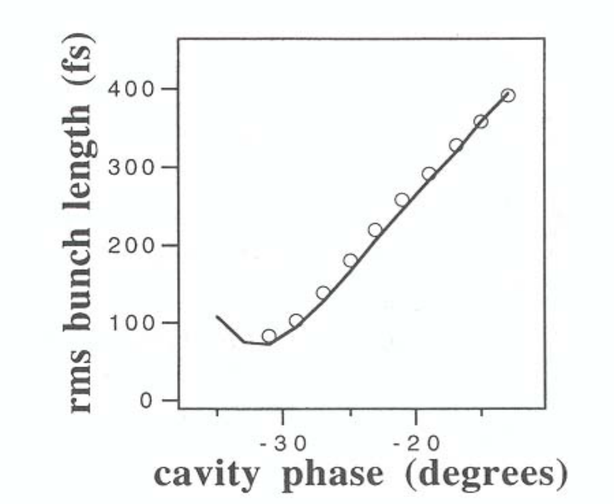
Promisses from ERL:
improved time resolution

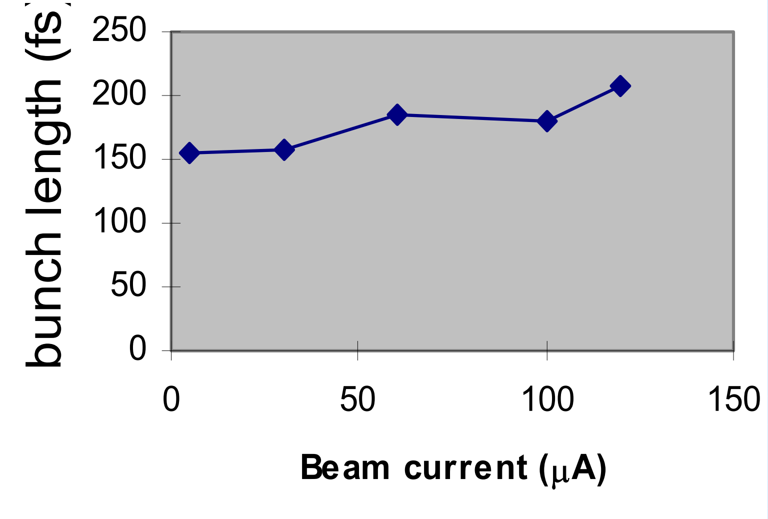
Electron Bunch Length & Peak Current

Machine	E [GeV]	σ_L [ps]	I_{pk}[A]
ALS	1.5	14	
SLS	2.4	13	
SOLEIL	2.5	12	
NSLS XRAY	2.8	158	90
DIAMOND	3	10	
ESRF	6	21-61	295
APS	7	17-54	
LBL ERL	3	1/0.025	(x-ray comp.)
PERL	3-7	0.1-0.4	600

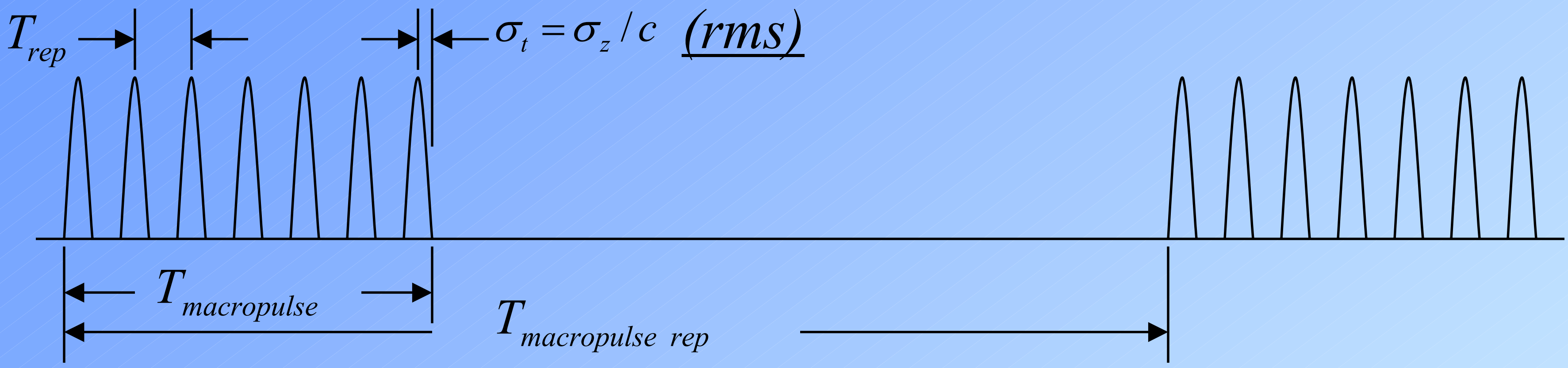
Courtesy of Jim Murphy

**Measured time resolution at Jefferson Lab,
G. Krafft, Science WS 2002**





Promises from ERL: **arbitrary puls pattern with good dynamic range**



Puls pattern is ideal for pump & probe experiments

CW = 1,3 GHz,

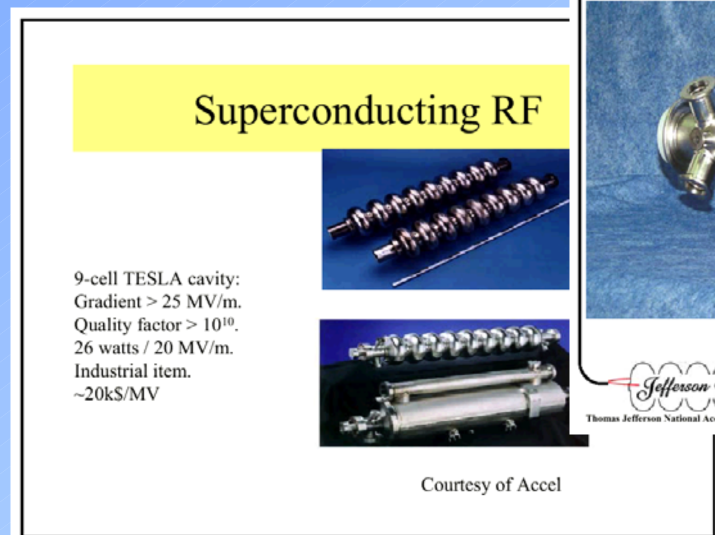
- **thermal load in individual pulses will not destroy samples**
- **thermal load is constant for the optical beam elements**

Problems for ERL:

Energy recovery: G. Krafft

Same-cell energy recovery with cw beam current up to 5 mA and energy up to 50 MeV has been demonstrated at the Jefferson Lab IR FEL. Energy recovery is used routinely for the operation of the FEL as a user facility

Supra conducting LINAC in CW-mode



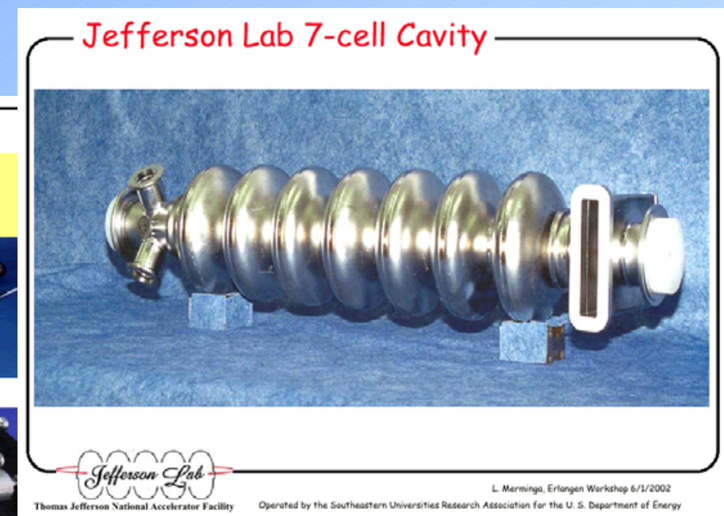


Photo injector; (Ilan Be Zvi)
Life time and operation at 1,3 GHz

ERLs: a lot remains to be done:

G. Krafft, JLAB:

WS 27. Sept. -29. Sept 2002

- Low emittance production & preservation
  - Achieving thermal emittance from gun (emittance compensation)
  - CSR, wakes (77 pC, not 1 nC!)
- Photocathode longevity at high average current (vacuum)
- Longitudinal phase space preservation in bunching (curvature correction)
- BBU in the main linac (HOMs damping)
- Beam loss ~ μA (halo)
- Highest Q_0 possible (reduced heat load and best efficiency)
- Diagnostics …

- But, the present knowledge on beam recirculation and its limitations in a superconducting environment, leads us to think that recirculating accelerators of several GeV energy, and with beam currents approaching those in storage ring light sources, are possible.

G. Kulipanov, Budker Institute, Novosibirsk

Concluding remark on ERLSYN machine workshop 31. Mai-1. Juni 2002:
Fourth generation SR light sources based on accelerators – recuperators is mainly the issue of funding

Many thanks

E. Steffens
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Cornell: D. Bilderback
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ERLSYN machine workshop
31. May / 1. Juni 2002

ERLSYN Science workshop
27. Sept. -29. Sept 2002