



FLS 2006

37th ICFA Advanced Beam Dynamics Workshop on Future Light Sources

FLS2006ワークショップと FLASH (TTF/VUV-FEL)見学

2006/06/09 ERL検討会

KEK 坂中章悟



FLS 2006

37th ICFA Advanced Beam Dynamics Workshop on Future Light Sources

概要

- ・ ICFA主催の次世代放射光源に関するワークショップ
- ・ 1996 (ESRF), 1999 (ANL), 2002 (SPring-8), 2006 (DESY)

ワークショップの構成 (合計150名参加)

- ・ Plenary session (共通)
- ・ WG1 (蓄積リング)、座長 K. Harkay (ANL), A. Ropert (ESRF)、 26名
- ・ WG2 (ERL)、座長 G. Hoffstaetter (Cornell), S. Smith (Daresbury), 20名
- ・ WG3 (FEL)、座長 Z. Huang (SLAC), L. Serafini (INFN-Milano), 55名
- ・ WG4 (低エミッタンス電子銃)、座長 W. Graves (BNL, MIT),
M. Krasilnikov (DESY), F. Stephan (DESY), 20名
- ・ WG5 (ビーム診断と安定化)、J. Byrd (LBNL), D. Noelle (DESY) 27名

日本からの参加者

- ・ 羽島 (JAEA)、大沢 (KEK)、坂中 (KEK)、高木 (ISSP)
- ・ 川島 (SPring-8)、浜 (東北大)



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発表スライドはウェブ上で公開中

<http://adweb.desy.de/mpy/FLS2006/proceedings/HTML/SESSION.HTM>

Plenary Talk のハイライト

- W. Wurth, First Experimental Experience at FLASH
- J.R. Schneider, Trends in X-ray Synchrotron Radiation Research
- D. Bilderback, Energy Recovery Linac Experimental Challenges
- F. Gruener, Design Considerations of table-top FELs
- D.E. Moncton, Inverse Compton Scattering: A Small Revolution in X-ray Sources and Applications
- E.L. Saldin, Schemes for generation of attosecond pulses in X-ray FELs



First Experimental Experience at FLASH



User Operation since
August 2005

Photon energy 30-200 eV
 10^{13} Photons/Pulse
 10^5 Pulses (< 100 fs)
Peak power 1 GW



- FLASH performance
- User operation
- Some experimental results

W. Wurth
Institut für Experimentalphysik
Universität Hamburg

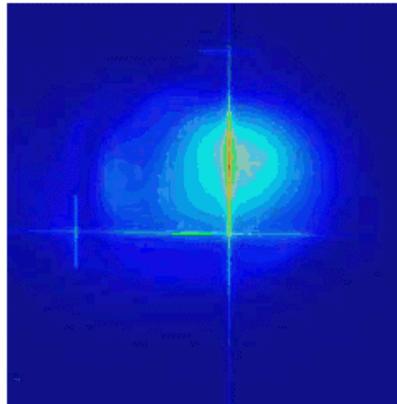




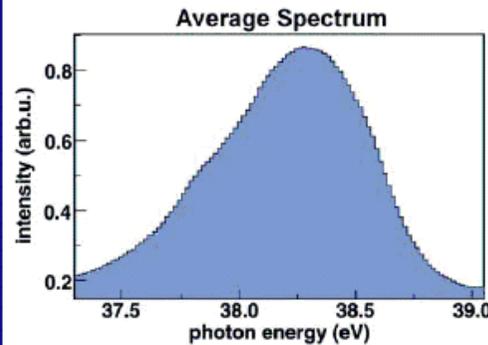
FLASH performance at 32 nm



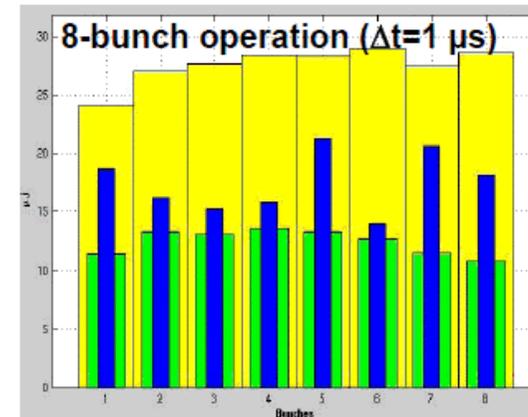
Spatial profile



Spectral distribution



2Hz/multi-bunch (≤ 30)



■ max
■ average
■ single

Parameter	Expected (08.04)	Measured
Wavelength	30 nm	32 nm
Pulse duration	15-50 fs	20-40 fs
Pulse energy	50-150 μJ at saturation	up to 130 μJ (mostly 5-10 μJ) onset of nonlinear regime
Bandwidth	0.8%	0.5-1.0%
Divergence	70-80 μrad	< 150 μrad





User operation Aug. 2005-Feb. 2006



total available beamtime:
16 weeks with 13 user shifts
+ 1 maintenance shift per week

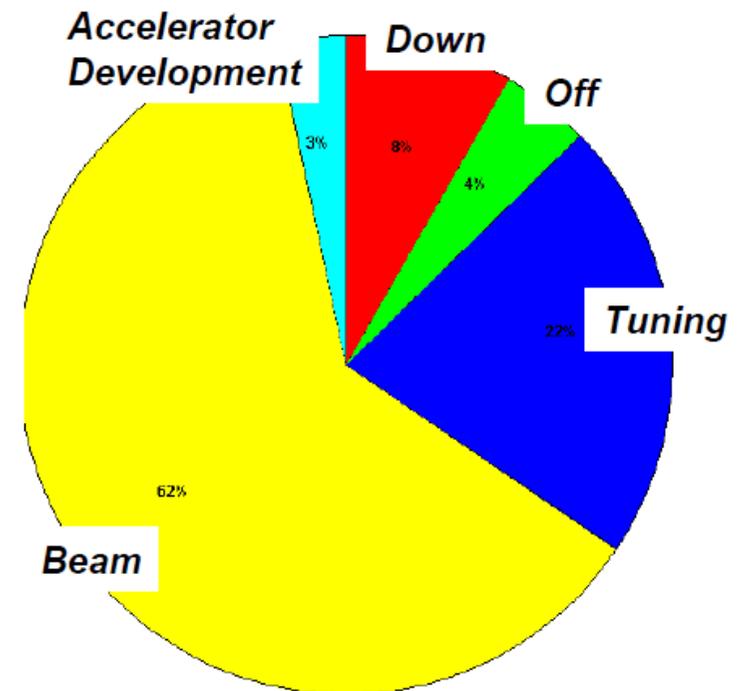
» *208 user shifts total (12 hour shifts)*

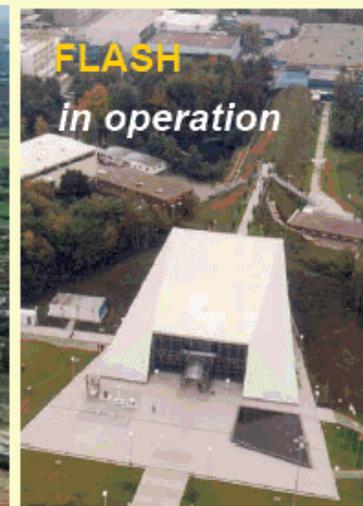
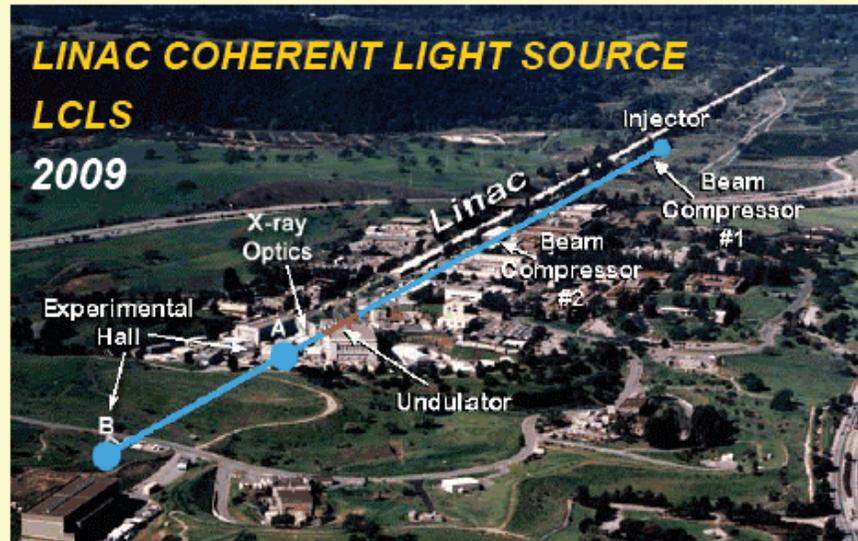
14 out of 16 projects had beamtime
2 are scheduled in May' 06

roughly 10-14 shifts/project



User operation 15.08. – 04.09.2005





Energy Recovery Linac Experimental Challenges



CHESSE & LEPP

Donald Bilderback^{1,2,}*

*¹Cornell High Energy Synchrotron Source, ²School of Applied and Engineering Physics
Cornell University, Ithaca, New York,
dhb2@cornell.edu*

1. Introduction to ERLs
2. Start with ERL layout + x-ray beam lines
3. Look at machine features
4. Look at the x-ray experiments
5. Add up the challenges – they are many!
6. Conclusions



*for the ERL/LEPP/Chess developers team



Cornell University
Cornell High Energy Synchrotron Source

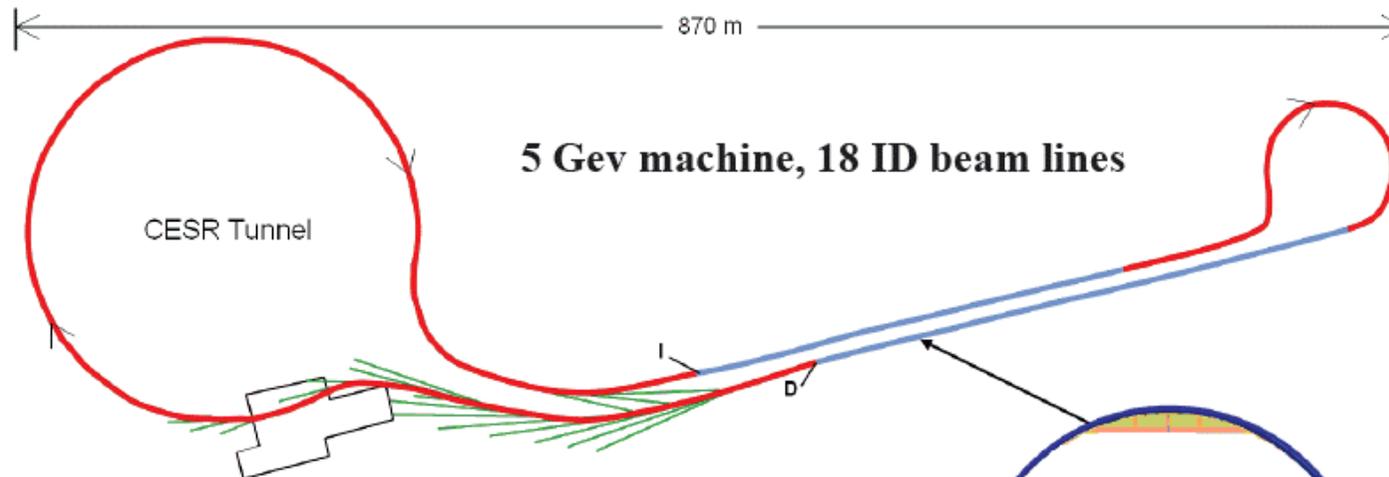
FLS2006 in Hamburg, Germany May 15, 2006

Cornell ERL Layout

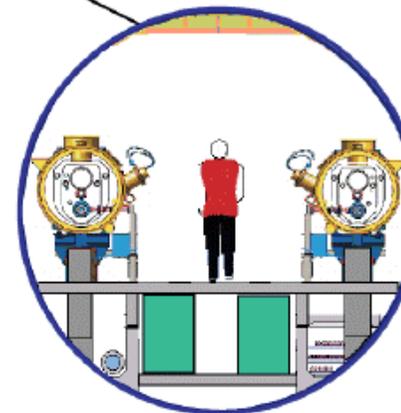
(current version, layout still under development)



CHESS & LEPP



Preliminary layout view of an ERL upgrade to CHESS in the present CESR tunnel. A new tunnel with a return loop will be added to CESR. Electrons are injected into superconducting cavities at (I) and accelerated to 2.5 GeV in the first half of the main linac, then to 5 GeV in the second half. The green lines show 18 possible beamline locations. Electrons travel around the CESR magnets clockwise and re-enter the linac out of phase. Their energy is extracted and the spent electrons are then sent to the dump (D).



Two superconducting linacs in one tunnel accelerate the electrons to 5 GeV. Person shown for scale.

3 Basic Operating Modes

Hi-flux: 30 pm emittance, 100 mA, 77 pC, 1300 MHz repetition rate
electron energy spread of $2E-4$ (5 pm, 100 mA long-term goal)

Hi-coherence: 8 pm, 25 mA, 7.7 pC, (5 pm, 100 mA long-term goal)

Ultra-fast: 511 pm, 1 mA, 1 nC, 1 MHz repetition rate



Cornell University
Cornell High Energy Synchrotron Source

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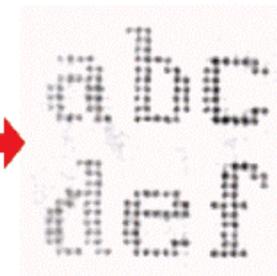
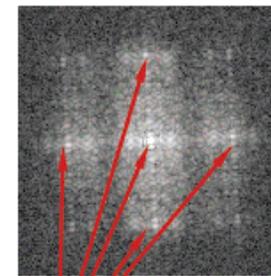
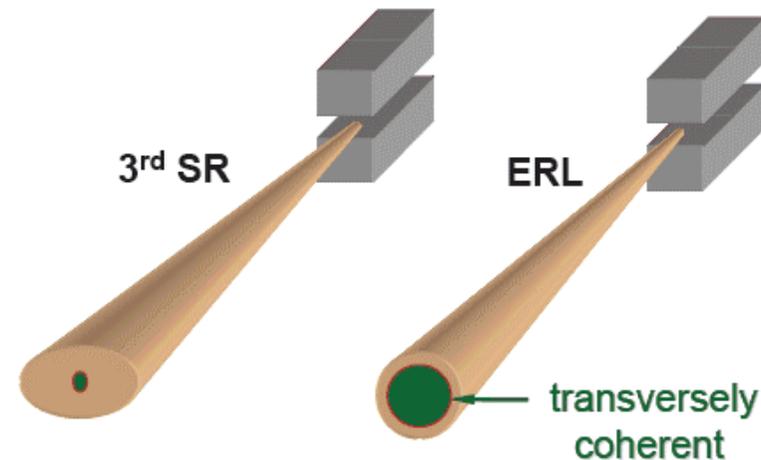


CHES & LEPP

Molecular Imaging

- Molecular imaging requires much higher lateral resolution => limit on optics
- To go beyond the limit, lens less diffraction imaging using a transversely coherent beam is an attractive alternative
- Coherent diffraction imaging is similar to crystallography, but for **noncrystalline** materials

- **Present Status:** using a pin-hole to select a coherent x-ray beam
- **Future ERL sources** would change this dramatically:
 - almost **fully coherent** x-ray beams
 - 3,000 fold increase in coherent flux
- **Open up structural science** to **noncrystalline** materials



Coherent X-rays

Miao et al. *Nature* (1999):
soft x-ray diffraction
reconstruction to 75 nm



Cornell University
Cornell High Energy Synchrotron Source

FLS2006 in Hamburg, Germany May 15, 2006

Design Considerations of *table-top* FELs

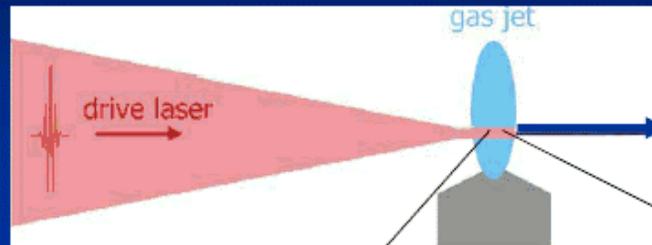
FLS 2006, May 15, 2006

LMU: F. Grüner, U. Schramm, S. Becker, R. Sousa, T. Eichner, **D. Habs**
MPQ: S. Karsch, M. Geissler, L. Veisz, J. Meyer-ter-Vehn, **F. Krausz**
UCLA: S. Reiche

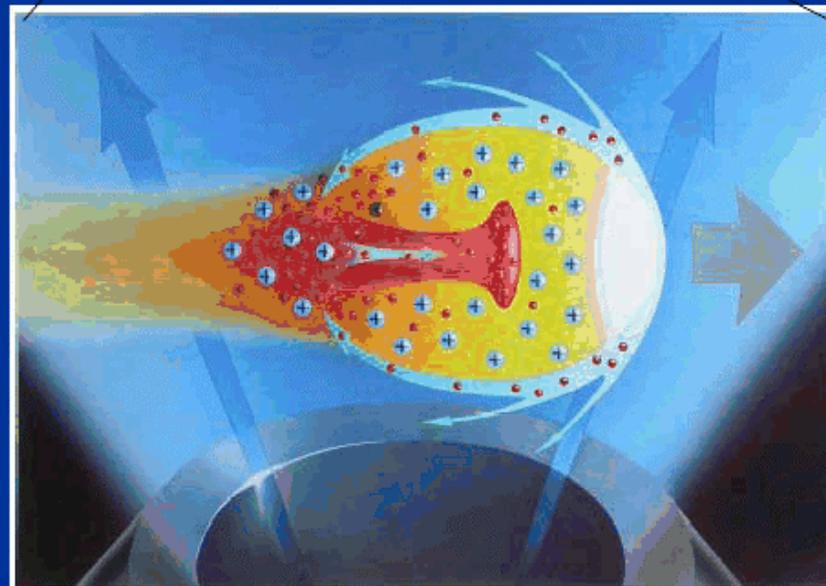
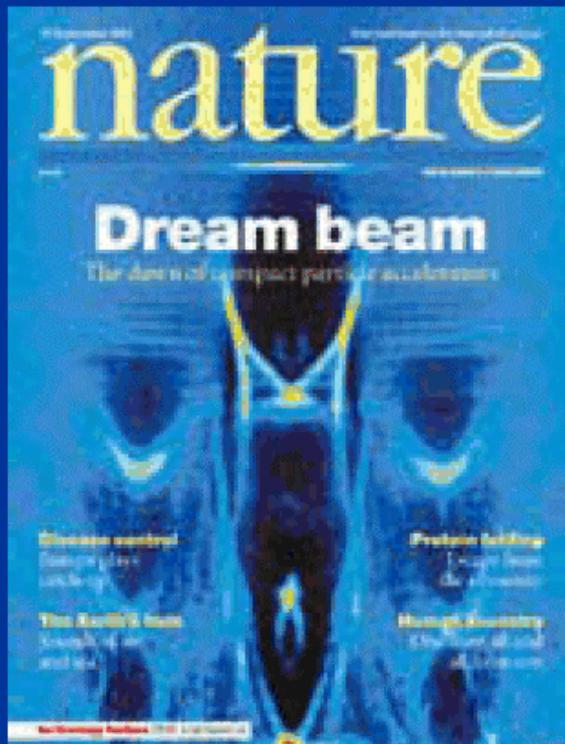
- laser-plasma accelerators
- principal possibility of *table-top* FELs
- possible VUV and X-ray scenarios
- experimental status

Laser-Plasma accelerators: “bubble acceleration”

TW laser,
5-50 fs



electron bunch:
e.g. 170 MeV (LOA),
rumor: 1.2 GeV (Berkeley)



F. Gruener 氏の スライドより

Principal possibility for table-top FELs

simplest estimate: **ideal** 1d Pierce parameter (no energy spread, emittance, diffraction, time-dependence)

$$L_{gain,ideal} = \frac{\lambda_u}{4\pi\sqrt{3}\rho}$$

current : few 100kA (classical: 5 kA)
und. period : few mm (class. few cm)

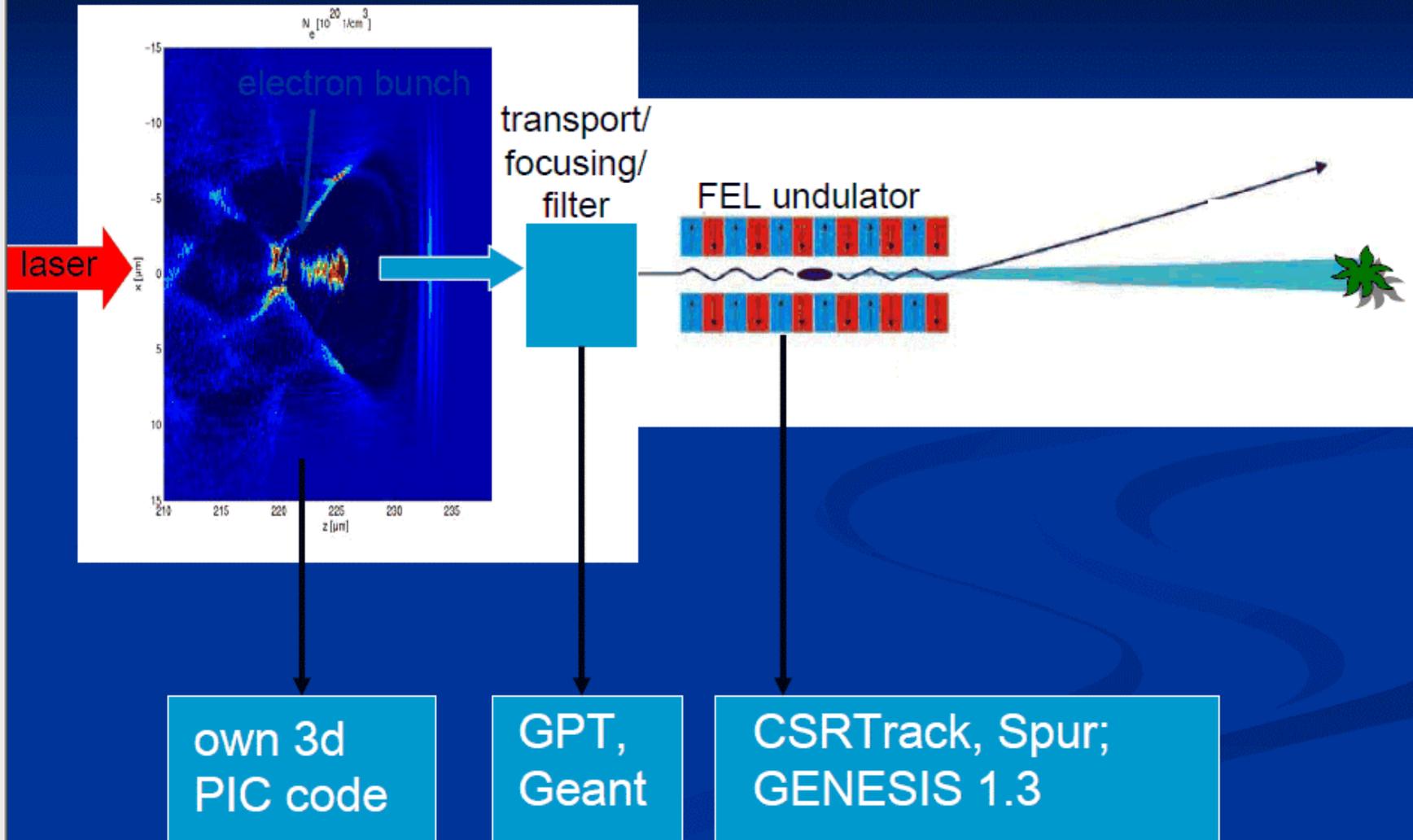
$$\rho = \frac{1}{2\gamma} \left[\left(\frac{I}{I_A} \right) \cdot \left(\frac{\lambda_u A_u}{2\pi\sigma_x} \right)^2 \right]^{1/3}$$

beam diameter (optimal!)

$$L_{gain,real}^{XieMing} = L_{gain,ideal} \cdot (1 + \Lambda)$$

$$L_{sat} \approx 15 \cdot L_{gain}$$

Start-to-End Simulations



Inverse Compton Scattering: A Small Revolution in X-ray Sources and Applications

David E. Moncton
Massachusetts Institute of Technology

ICFA Hamburg
May 16, 2006

In collaboration with Franz Kaertner, William Graves, and Winthrop Brown

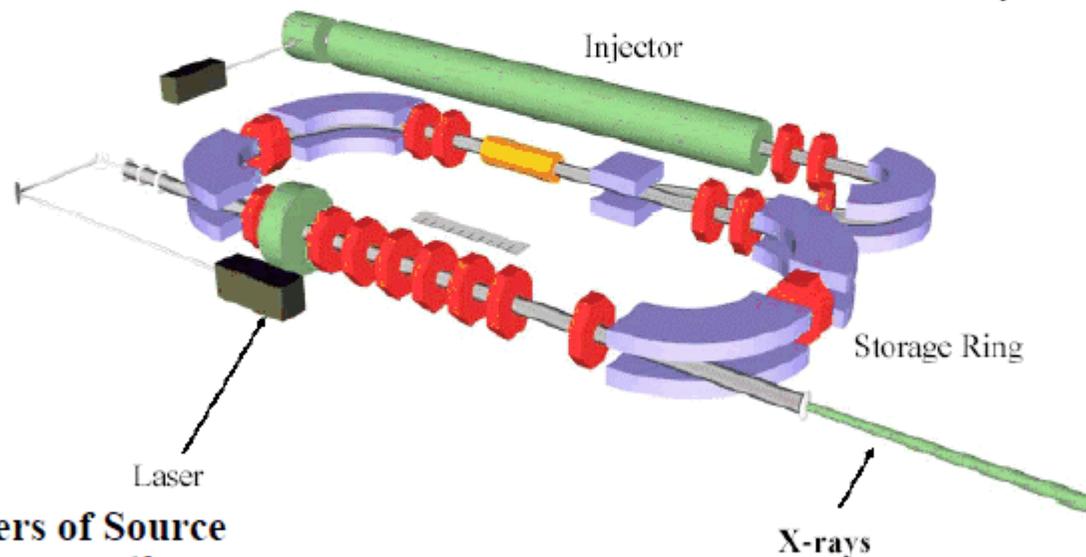


Lyncean Technologies Compact Source Concept

A Conceptual Picture of the CLS

(The 30 cm ruler in the middle is shown for scale.)

Courtesy of Ron Ruth

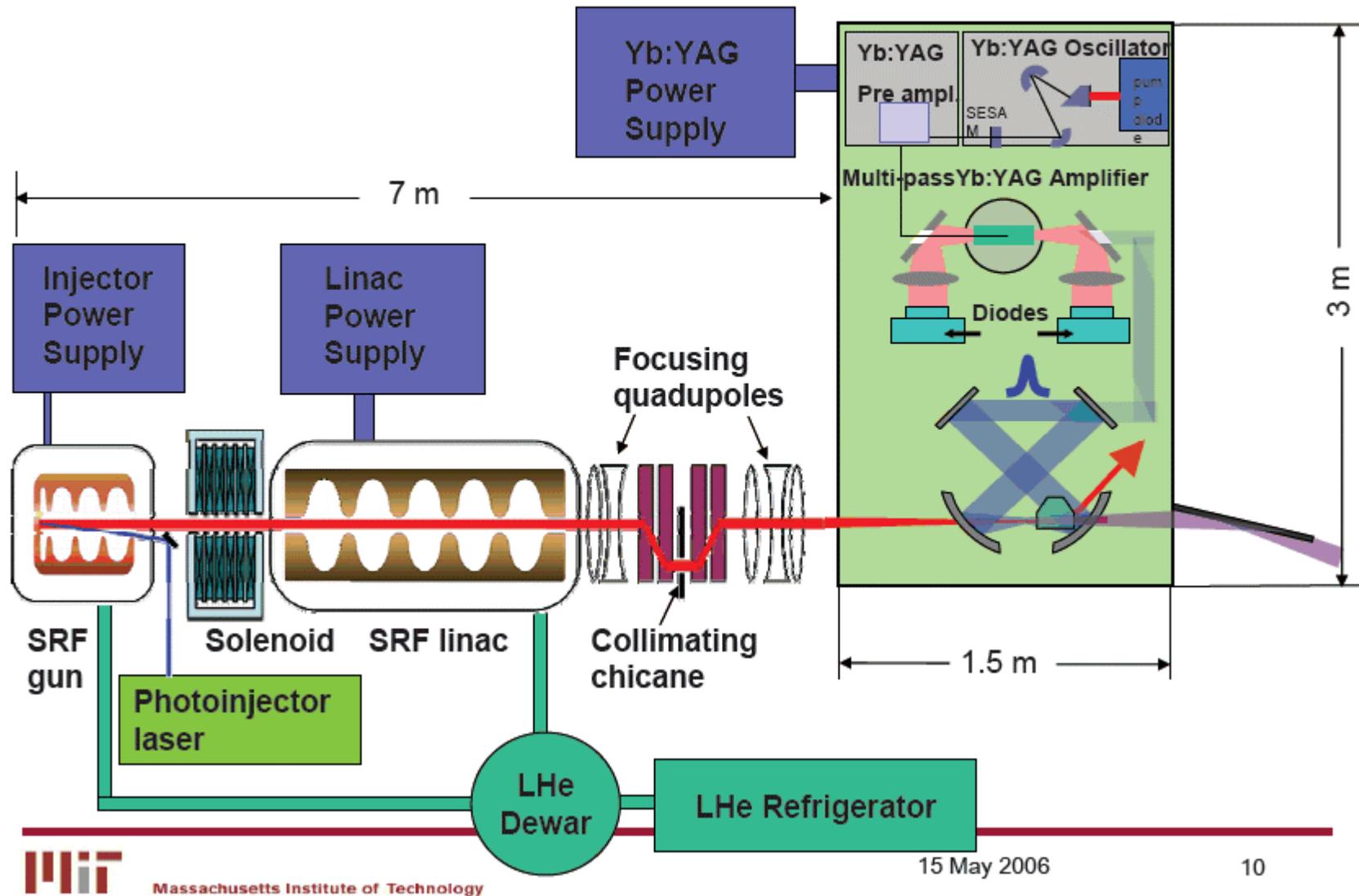


Parameters of Source

Average flux	10^{12} photons/sec
Source size	100 microns

“This is not a good time now for us to present results because we are in the middle of tune up”—5/11

MIT Inverse Compton Source Concept



D.E. Moncton 氏のスライドより



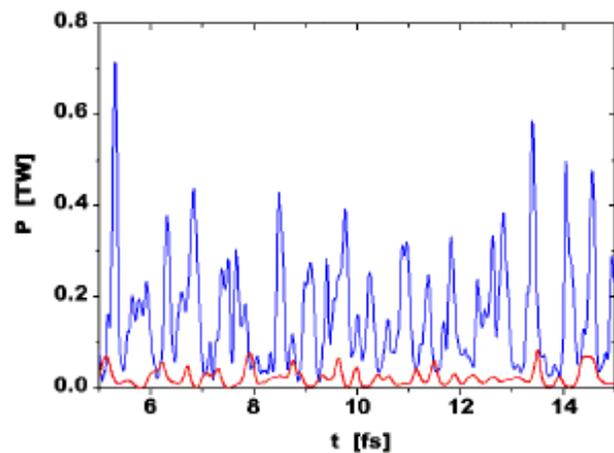
FLS2006 , Hamburg, May 17, 2006



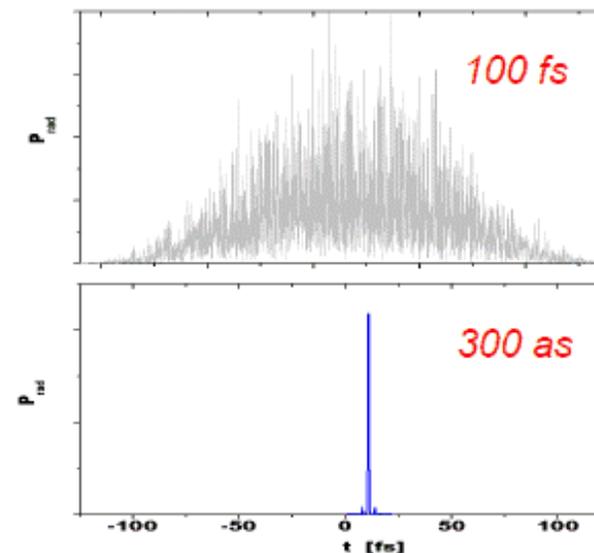
Schemes for generation of attosecond pulses in X-ray FELs

E.L. Saldin, E.A. Schneidmiller, M.V. Yurkov

*The potential for the development of XFEL beyond standard (SASE)
mode of operation:*



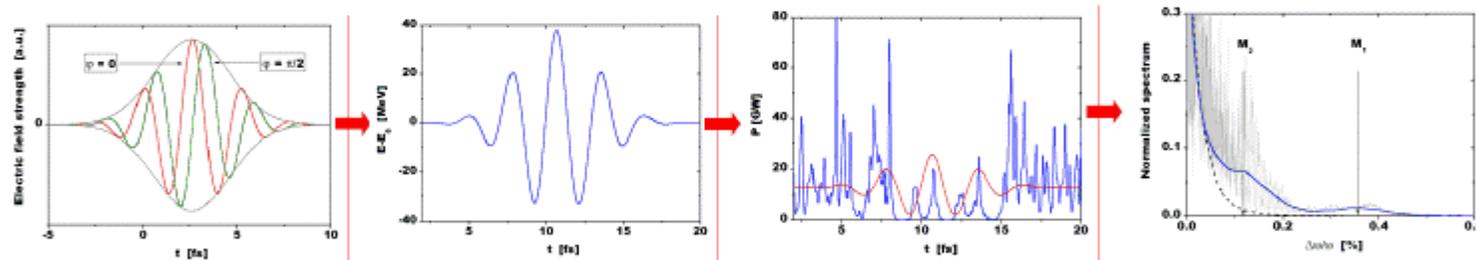
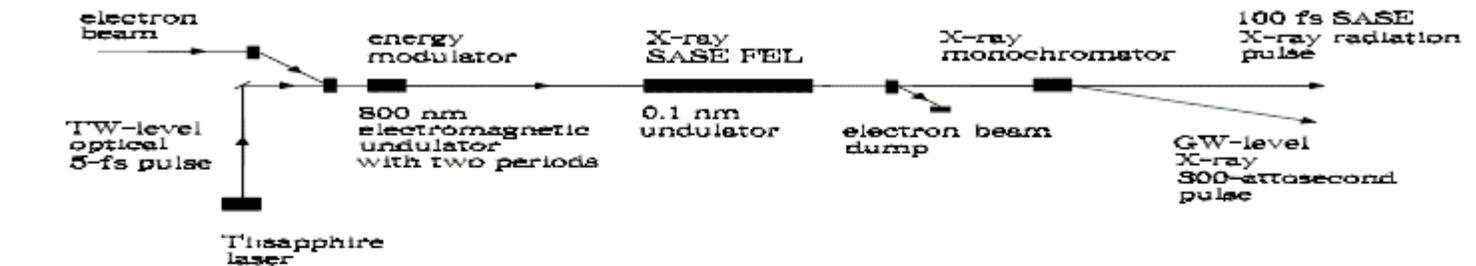
High-power (TW level) X-ray pulses



Ultrashort X-ray pulses



Generation of attosecond pulses in XFEL / „parasitic mode of operation“ /

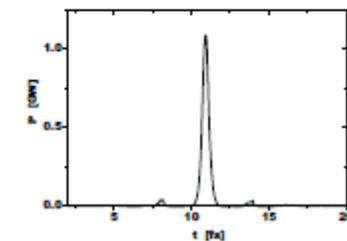


Slicing of electron bunch with fs-laser

SASE process

The laser-driven sinusoidal energy chirp produces a correlated frequency chirp of the resonant radiation $\delta\omega/\omega \simeq 2\delta\gamma/\gamma$. After the undulator, the radiation is passed through a crystal monochromator which reflects a narrow bandwidth. Since the radiation frequency is correlated to the longitudinal position within the beam, a short temporal radiation pulse is transmitted through the monochromator.

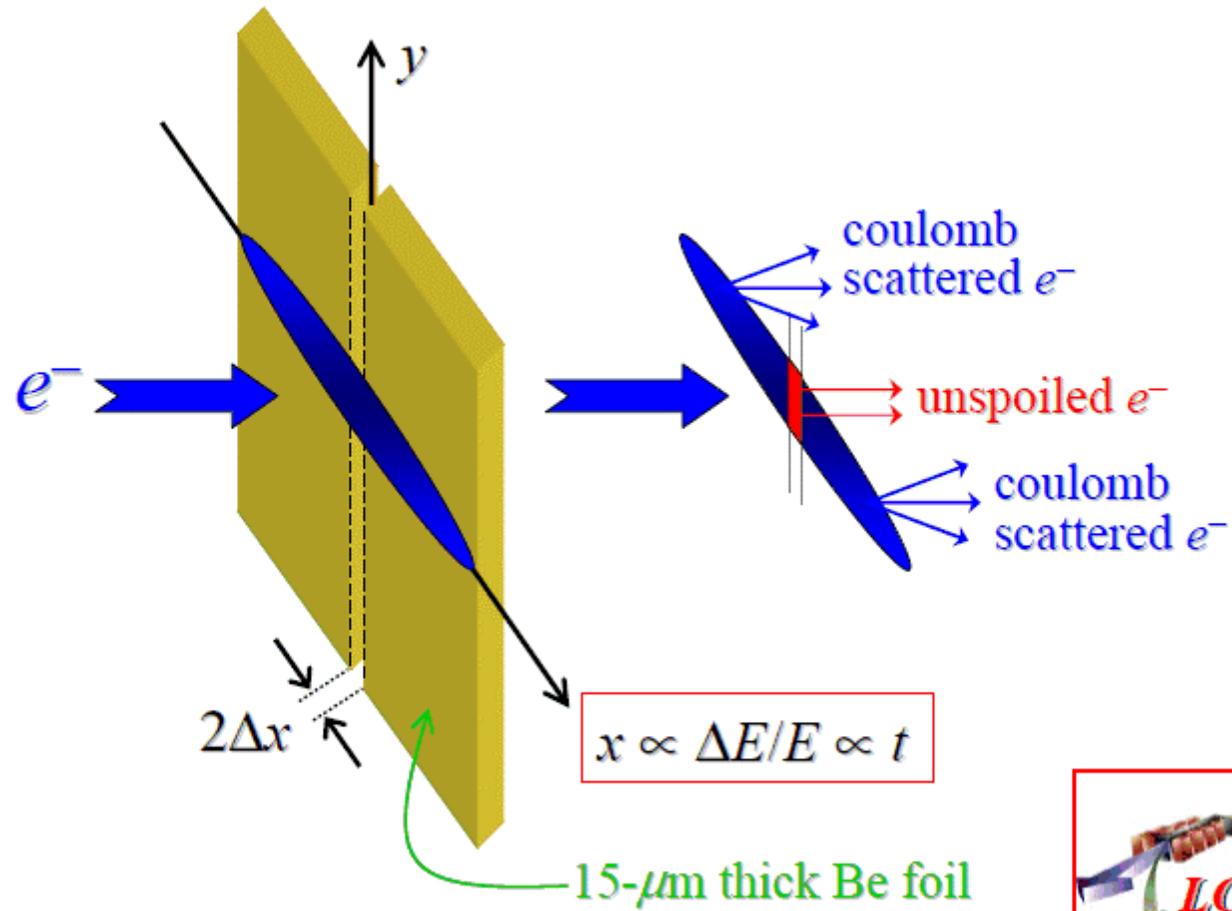
SSY, *Opt. Comm.*, 237(2004)153



Monochromator selects attosecond X-ray pulses



Slotted foil method

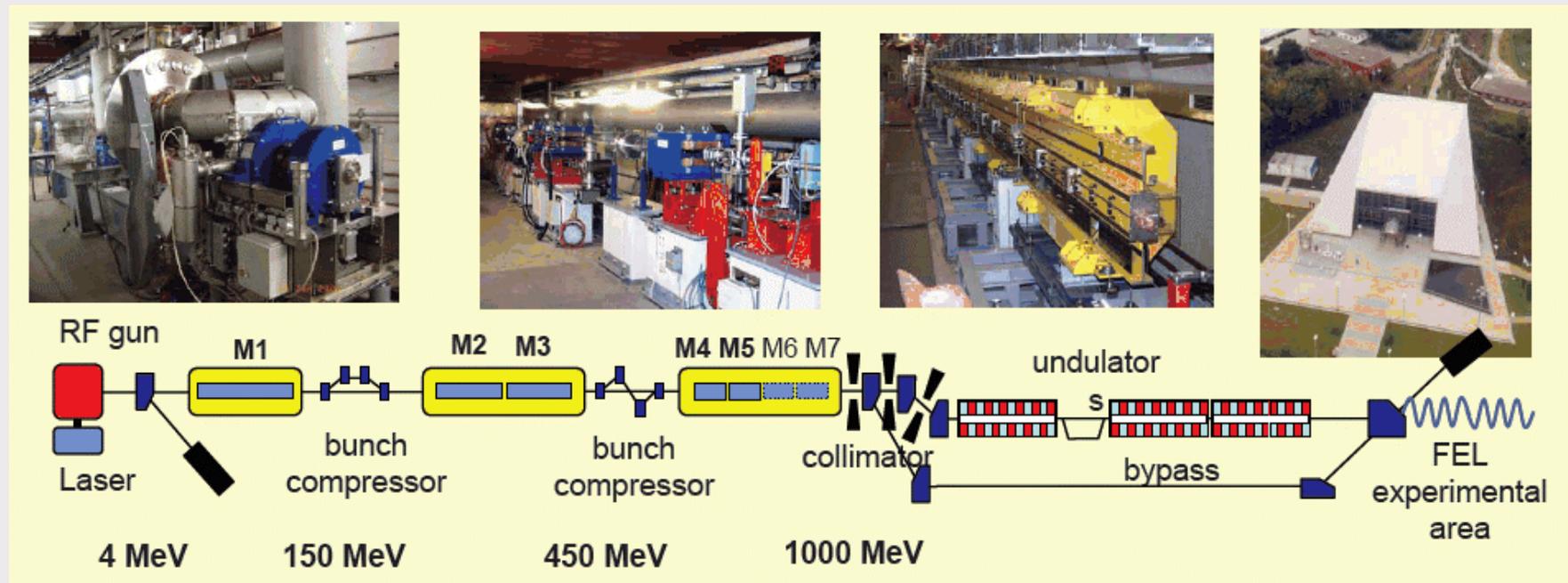


P. Emma et al., Proc. FEL 2004 Conf., p.333

Saldin 氏のスライドより

FLASH (Free electron LASer at Hamburg) (TTF/VUV-FELから改名)見学

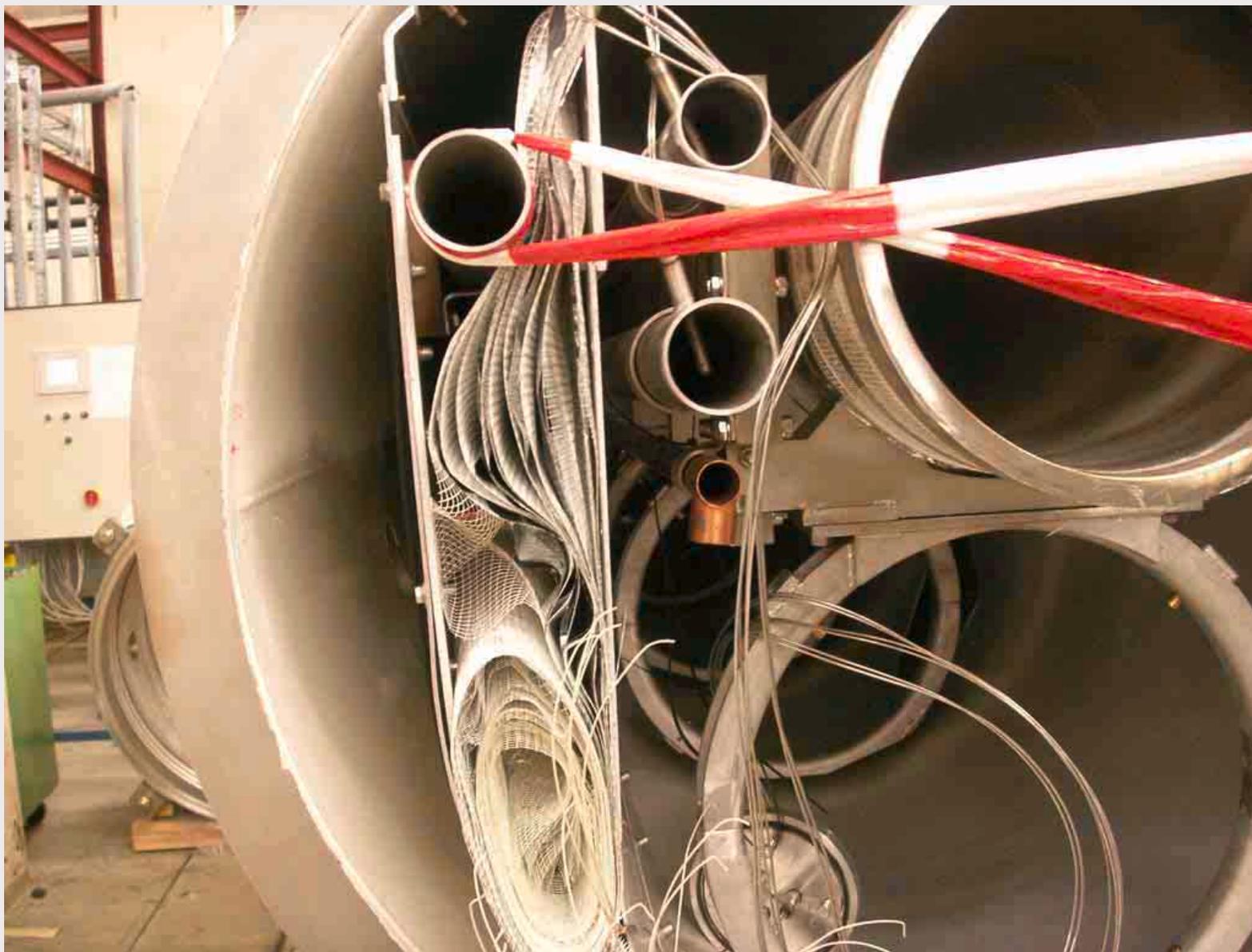
現在はビームエネルギー 700 MeV、FEL波長13 nm で運転。



Schneider 氏のスライドの一部を引用。



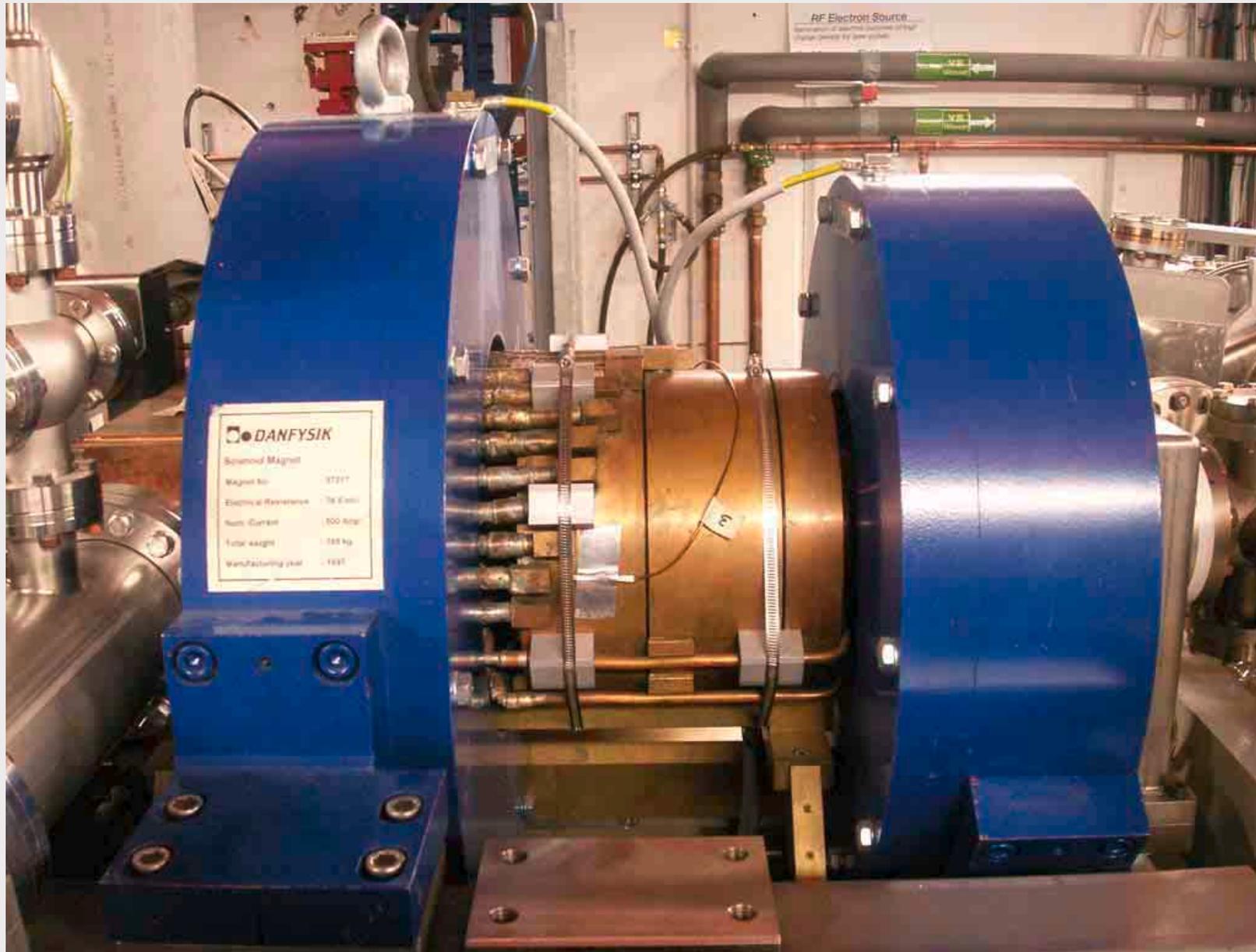
製造中のクライオモジュール。内部、下のパイプに超伝導空洞が入り、上の大きなパイプはヘリウムガスのリターン路。



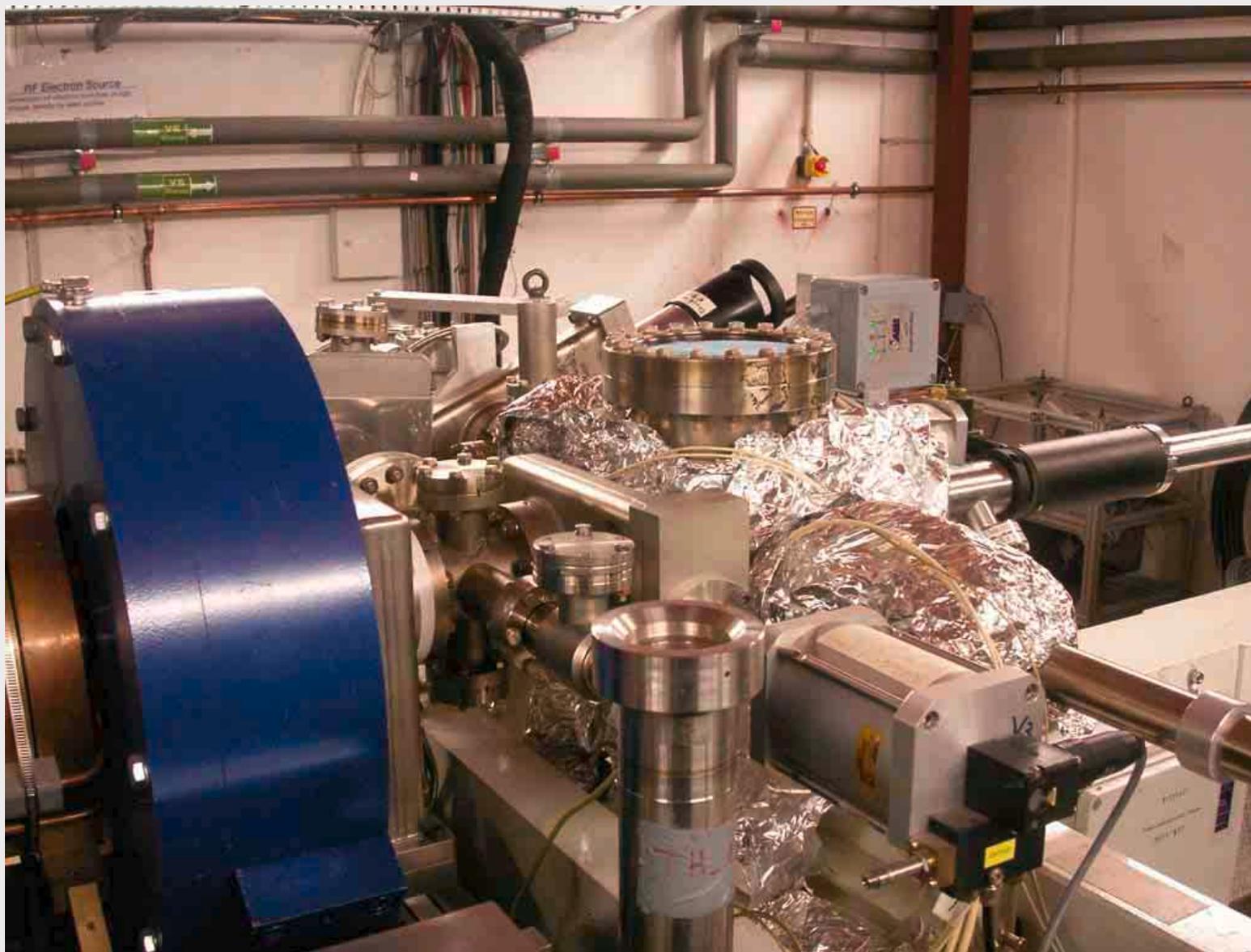
製造中のクライオモジュール(部分)



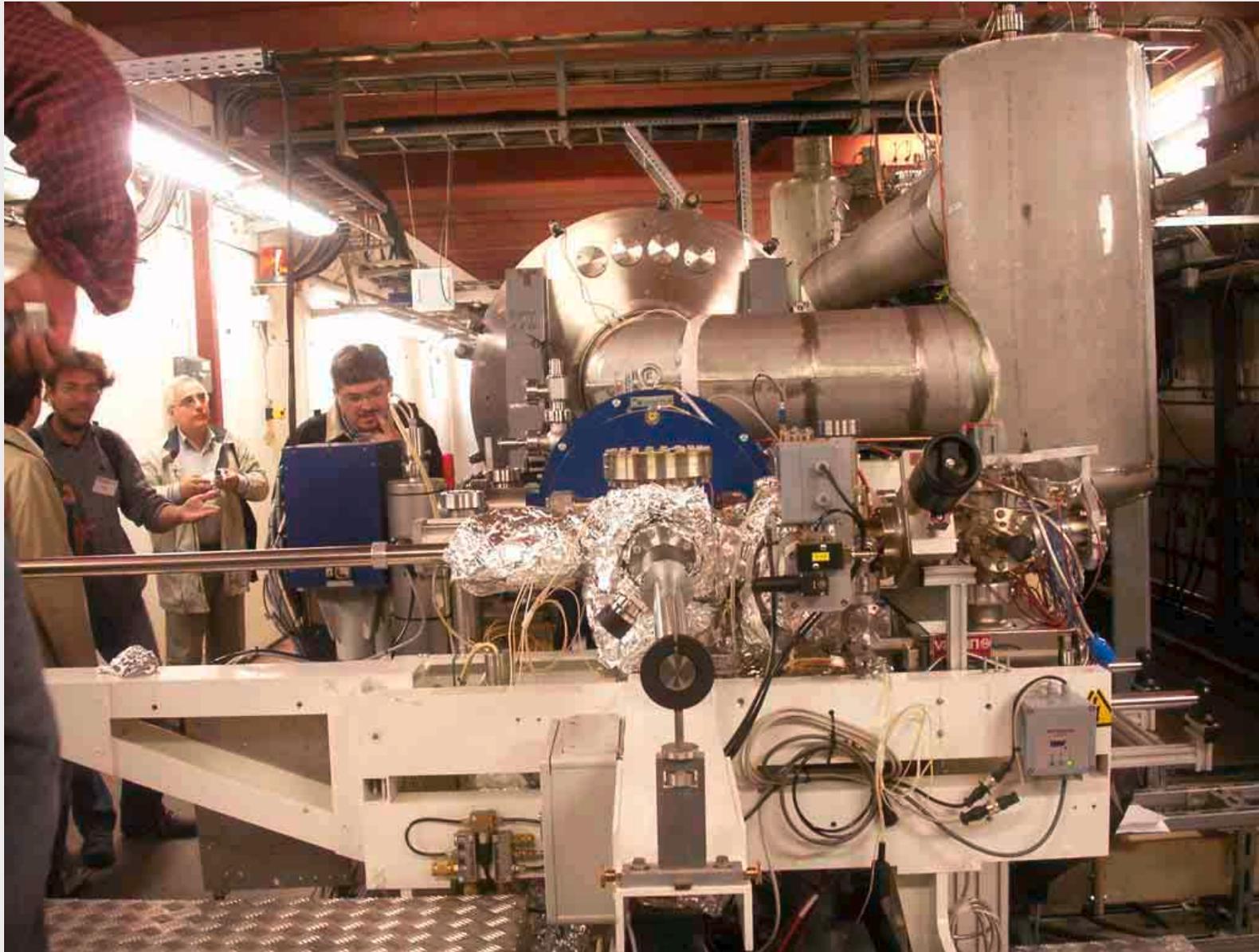
クライオモジュールの組み立てに使うジグ



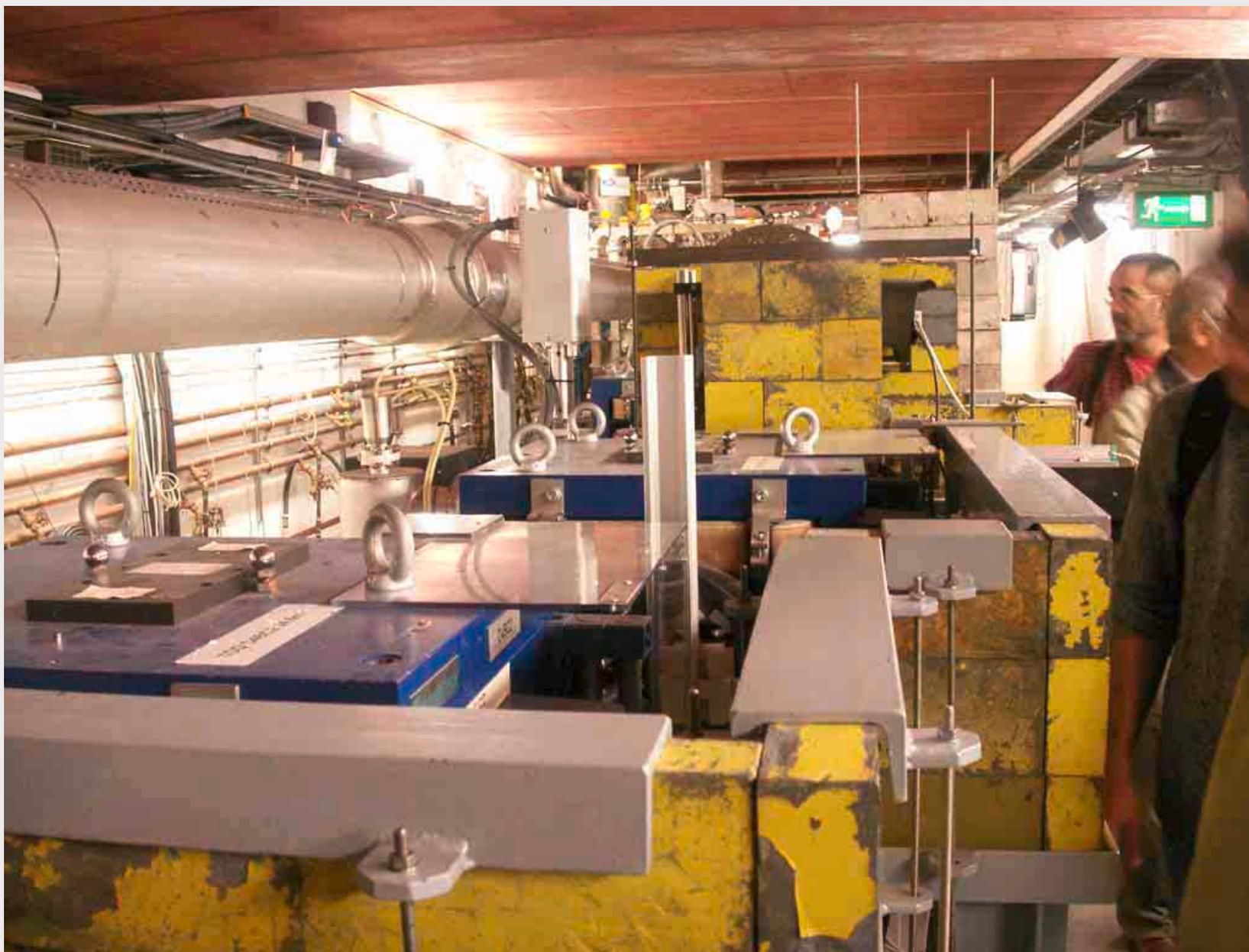
フォトカソードRF電子銃。右側が上流。青色はソレノイド。



フォトカソードRF電子銃。
右側がカソード(Cs_2Te)準備チェンバーとロードロックシステム。



フォトカソードのロードロックシステム。



1段目バンチコンプレッサー用シケイン。横に放射線遮蔽が設置されている。



クライオモジュール(たぶん前段から2台目)。



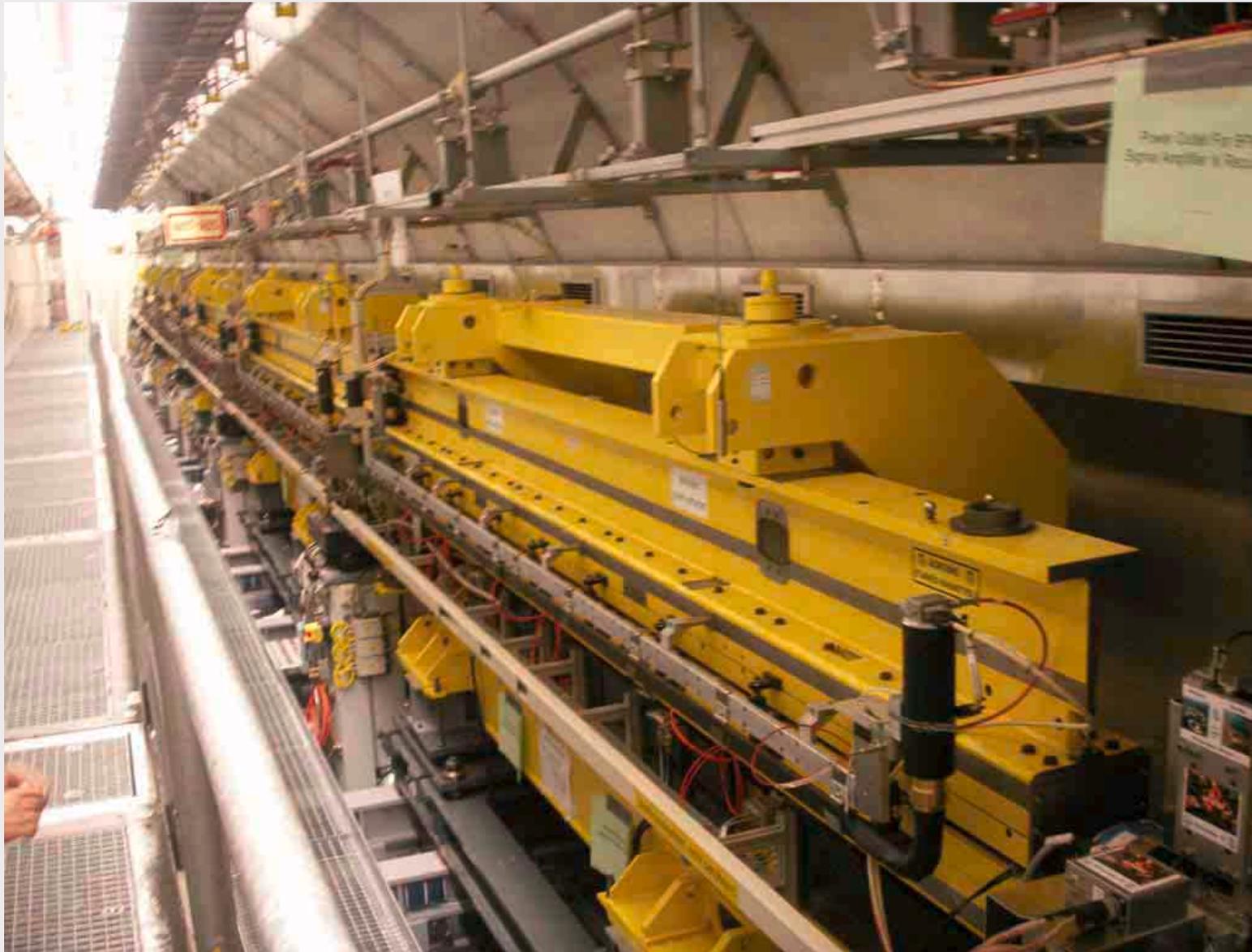
バンチコンプレッサー用シケイン(2段目)。幅広のチェンバーを使用。



クライオモジュール(下流から上流に向かって)。



超伝導リニアックからアンジュレータまでのビーム輸送路。
上側はビーム調整用のバイパスライン。



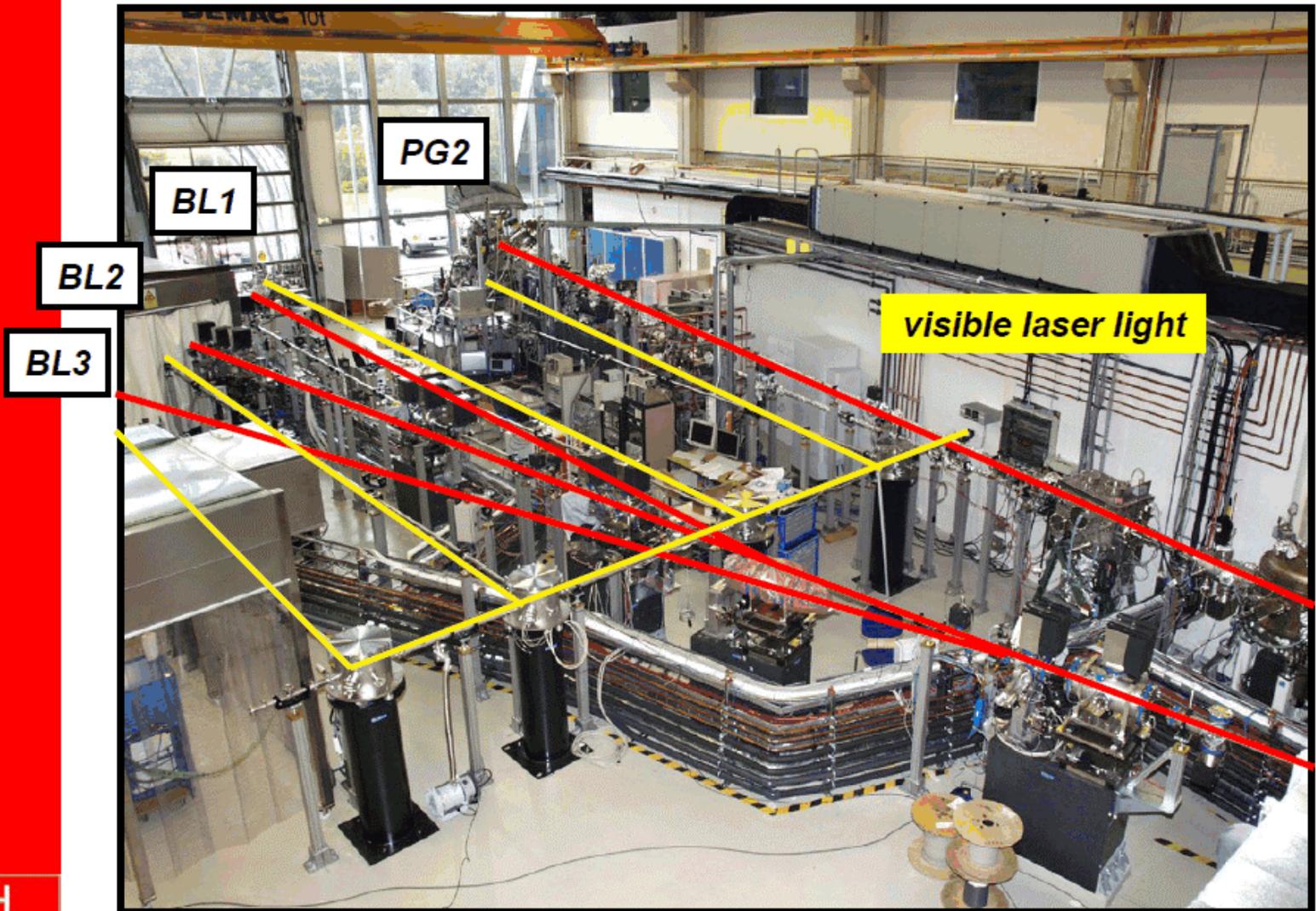
FEL用アンジュレータ。4.5m×6台。
周期長 27.3 mm、ギャップ12 mm(固定)、磁場 0.48 T (K=1.23)



FLASH 実験ホール (DESYホームページより)。



FLASH: the VUV-FEL User Facility at DESY



U+H

FLASH ビームライン (Wurth氏スライドより)。
現在4本のビームラインが稼働中。光はミラーで振り分ける。



ビームラインフロントエンド。ミラーは振動対策が重要。
アンジュレータとミラーの間(約 50m)にガスによるアッテネータがあり、
4~5桁強度を落とす。窒素または希ガス、0.1 mbar



ビームラインの一つ。現在アクティブな実験プロジェクトが16あり、約20週間
実験用に光ビームを供給した。ほとんどの実験は(可視)レーザー光も併用する。

FLASH施設見学のまとめ（案内：J. Feldhaus氏、HASYLAB）

- ・ ビームエネルギー 700 MeV、波長13 nm までの発振に成功。
- ・ 2005年から FEL光を実験に供給。20週のユーザー運転を行った。
- ・ 4～5の実験ステーションがあり、ミラーで光を振り分ける。
- ・ ミラーへのダメージを防ぐため、FEL 光は 4～5 桁落として使用している。
- ・ FEL光のバンド幅は1%程度であり、分光器で 10^{-4} にする。
- ・ 光ショット毎にパラメータが違っているので、ショット毎の情報を全て記録することが重要。