Summary of LERD at LER2016 low emittance ring desing

R. Bartolini

Diamond Light Source
and
John Adams Institute, University of Oxford

LER - SOLEIL
Paris, 28th October 2016

Low Emittance Ring Design

5 sessions – 25 talks; topics:

Commissioning/operation results (MAX IV, NSLS-II)

Updates/design progress (SIRIUS, SOLEIL, APS-U, CHESS, Diamond II, ALS U, HEPS, ELETTRA2.0, DIAMOND II, Spring-8, Lit-J)

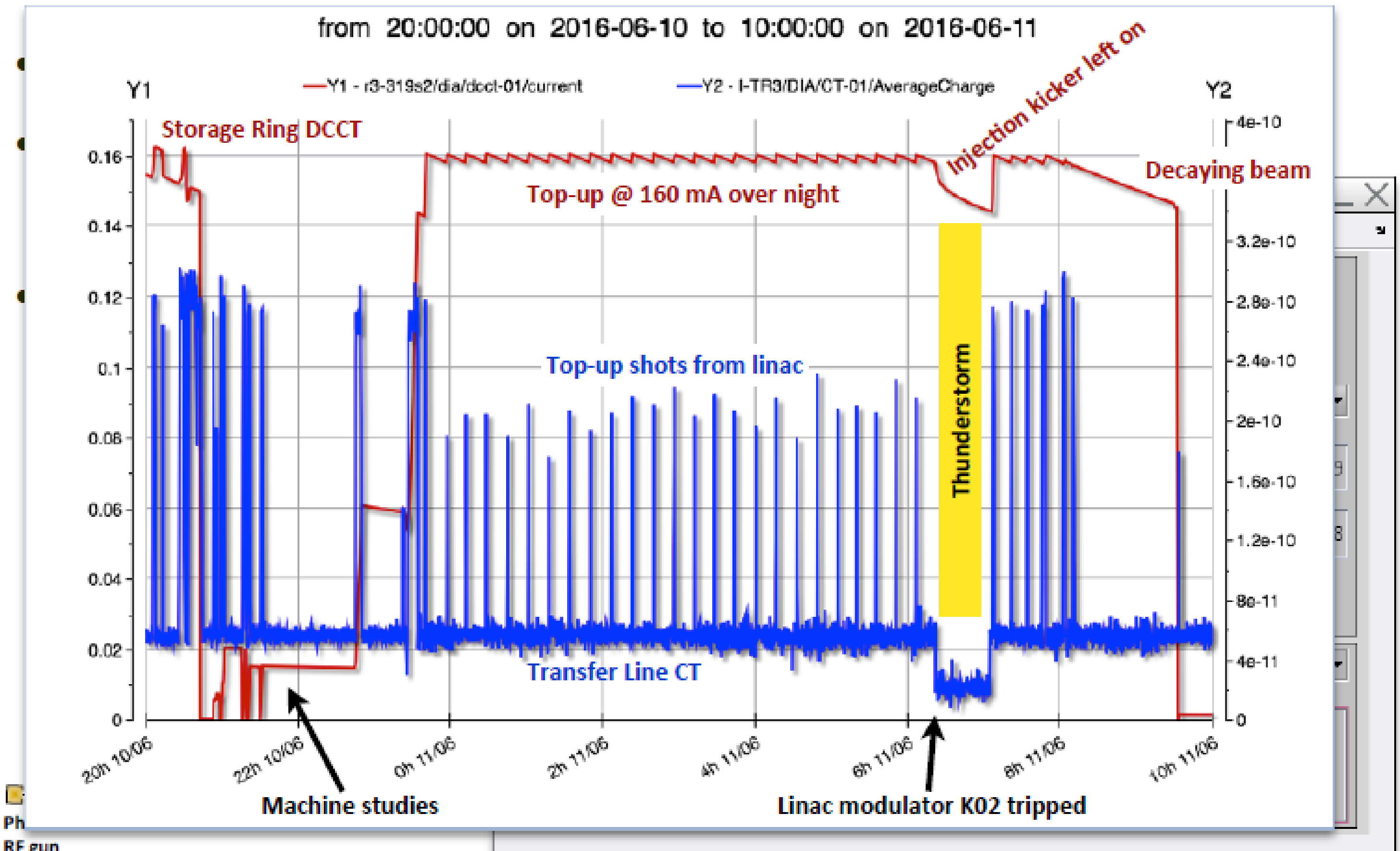
Optimisation tools (Huang, Ehrlichmann, Hua-Yu, …)

Analysis of performance (ESRF optics, ESRF-EBS lifetime, Spring-8 injection, Top-up injection in HEPS, V emittance APS, crab cavities at SPEARIII)

https://indico.cern.ch/event/574973/

MAX IV commissioning (S. Leemann)

3 GeV Storage Ring Commissioning (cont.)



Ph
RF gun

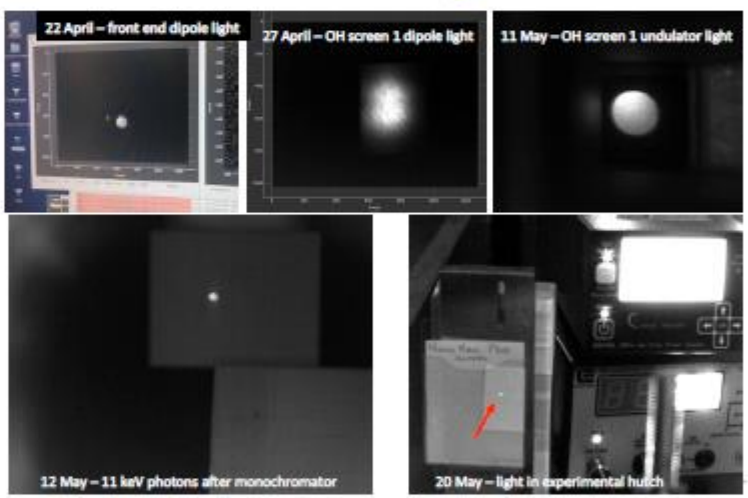
MAX IV commissioning (S. Leemann)

3 GeV Storage Ring Commissioning (cont.)

- First two IVUs installed during Feb 2016 shutdown
  - Hitachi, 18 mm period, 4.2 mm magnetic gap, 2 m length, 1.3 T peak field
  - for BioMAX and NanoMAX beamlines
- ID, FE & BL commissioning started Apr 2016

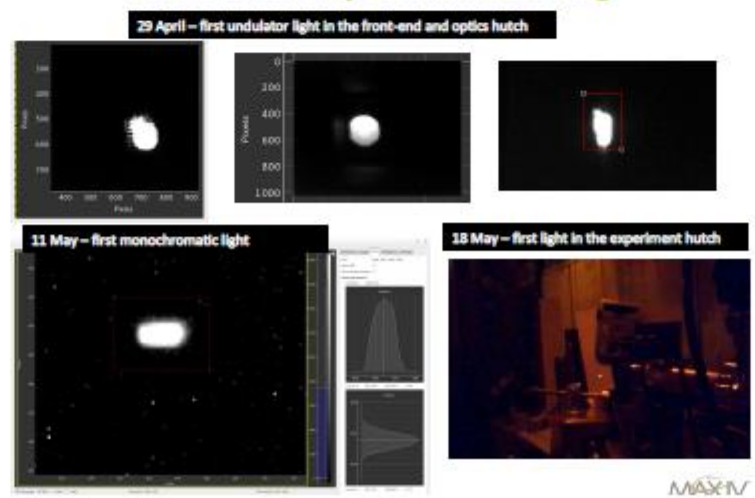
NanoMAX commissioning

Courtesy U. Johansson



BioMAX X-ray commissioning

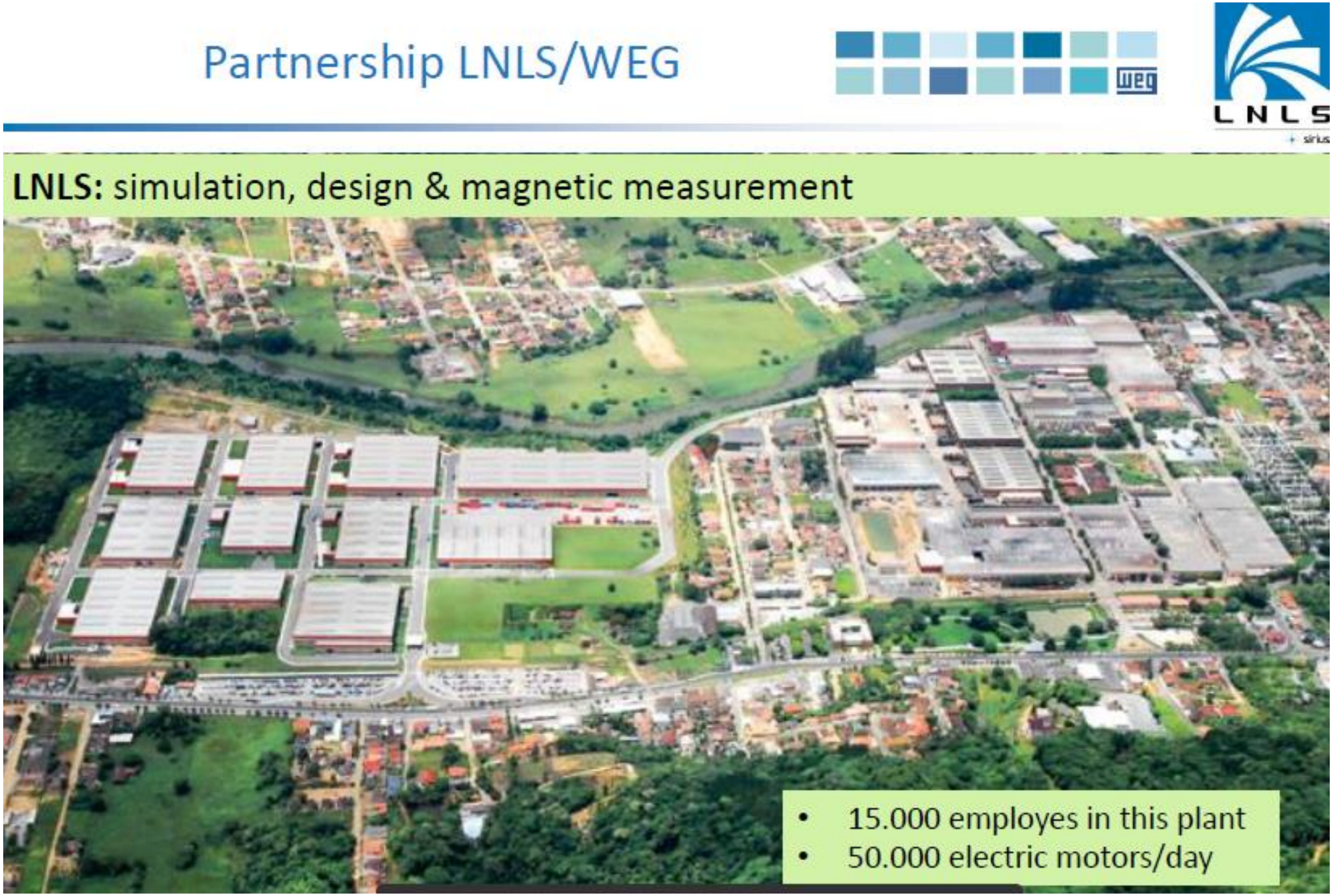
Courtesy T. Ursby



Sirius progress (F. E. De Sa)

Sirius building (Aug. 2016)

Sirius progress Magnets (F. E. De Sa)

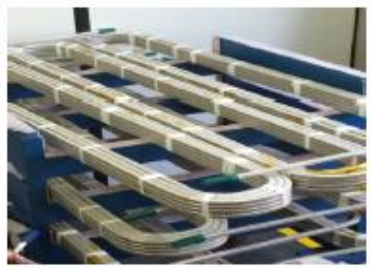


Sirius progress Magnets (F. E. De Sa)

Magnets production

LNLS

- A strategic decision for the production of Sirius magnets was to start with the booster magnets with tolerance requirements approaching the ones required for the storage ring.
- Delivery of all booster magnets will be completed by Dec. 2016.




CNPEM

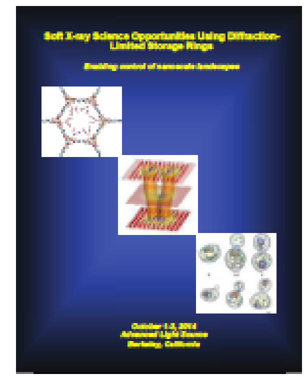
Sirius progress Vacuum (F. E. De Sa)

ALS-U (D. Robin)

ALS-U Timeline and Status

Jul 2013 BESAC Subcommittee on Future X-ray Pages from sxr_workshop_report.pdf
"The Office of Basic Energy Sciences should ensure that U.S. **storage ring** x-ray sources reclaim their world leadership position."

Oct, 2014 *Workshop on Soft X-ray Science Opportunities using Diffraction-Limited Storage Rings, LBNL* – result presented at Feb 2015 BESAC Meeting



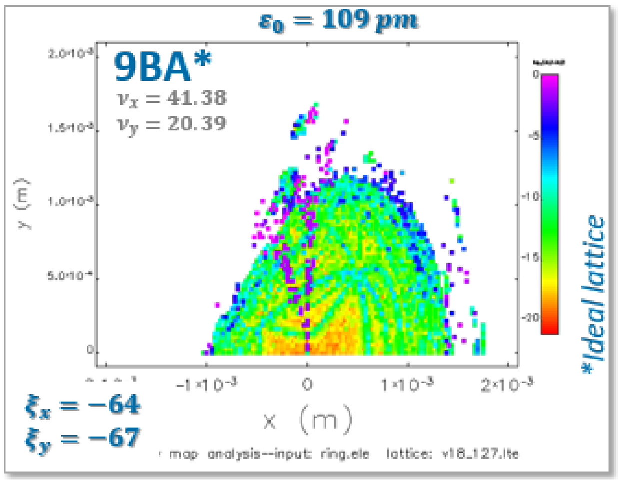
Since FY14 Received funding from LBNL for R&D as well as pre-project development. In FY16 received funding from BES for Research and Development for the Advanced Light Source Upgrade

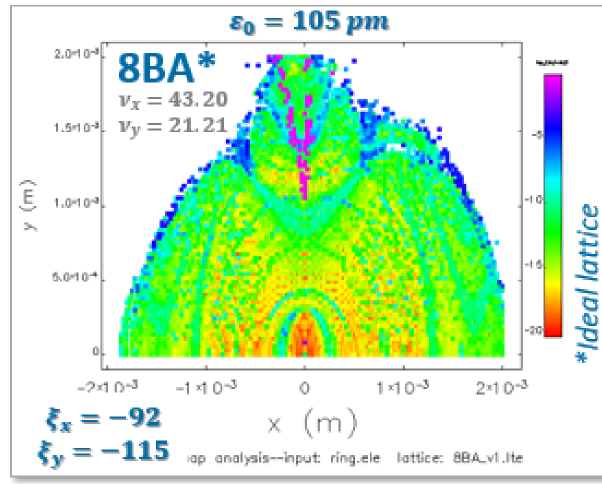
Jun 2016 BESAC Prioritization Panel grades ALS-U as "Absolutely Central" to contribute to world leading science and as "Ready to Initiate Construction"

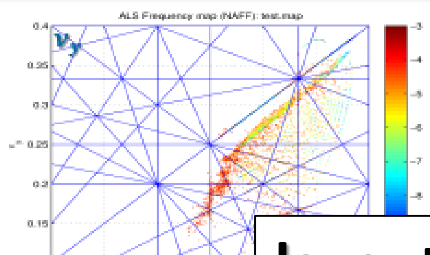
Sep 2016 ALS-U receives approval of Mission Need (CD-0) from DOE/BES

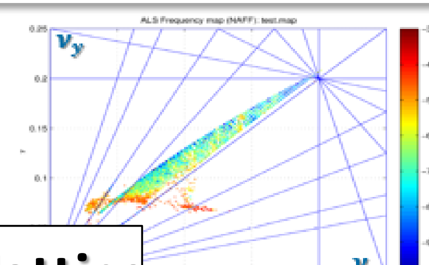
ALS-U lattice design (M. Venturini)

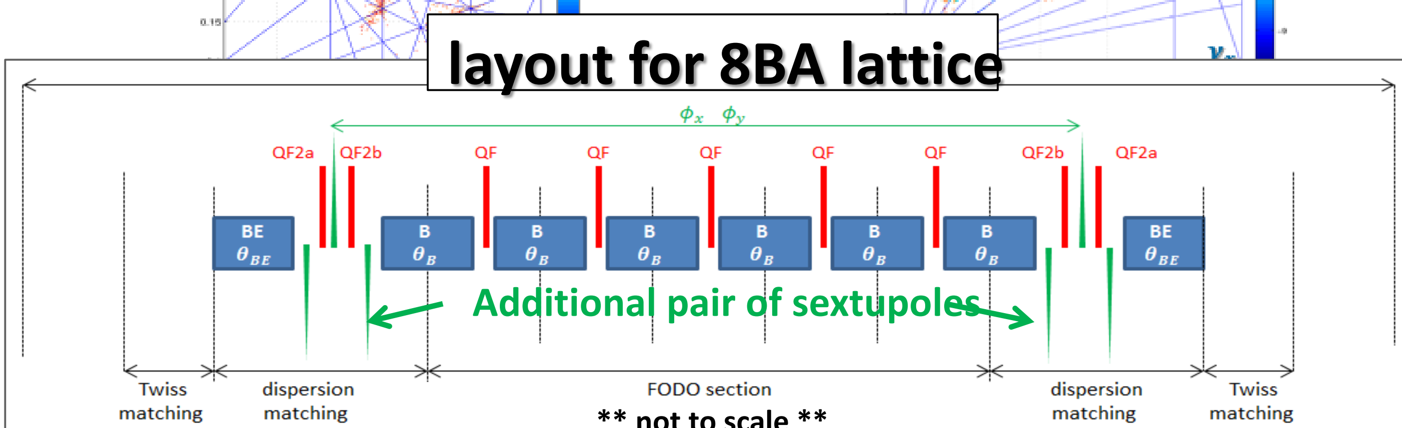
8BA DA is superior to 9BA's in spite of larger chromaticites





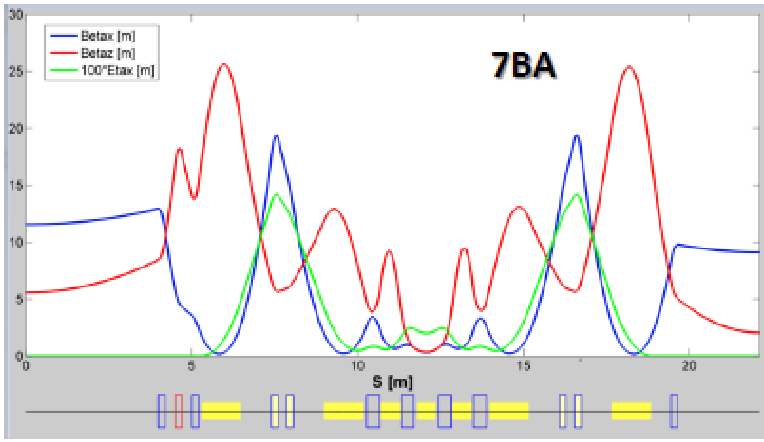


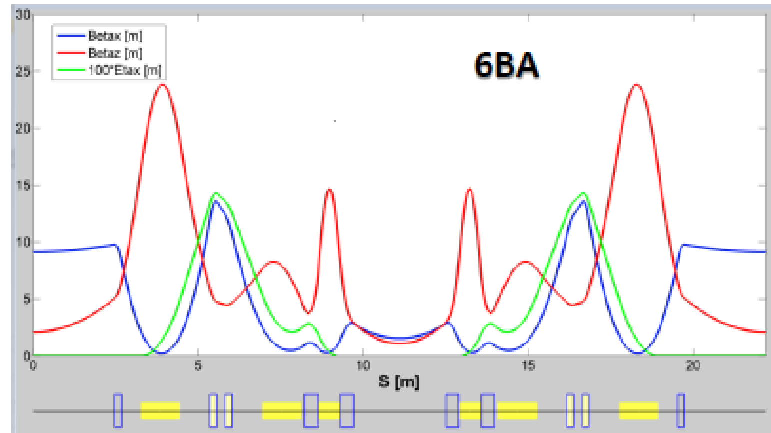


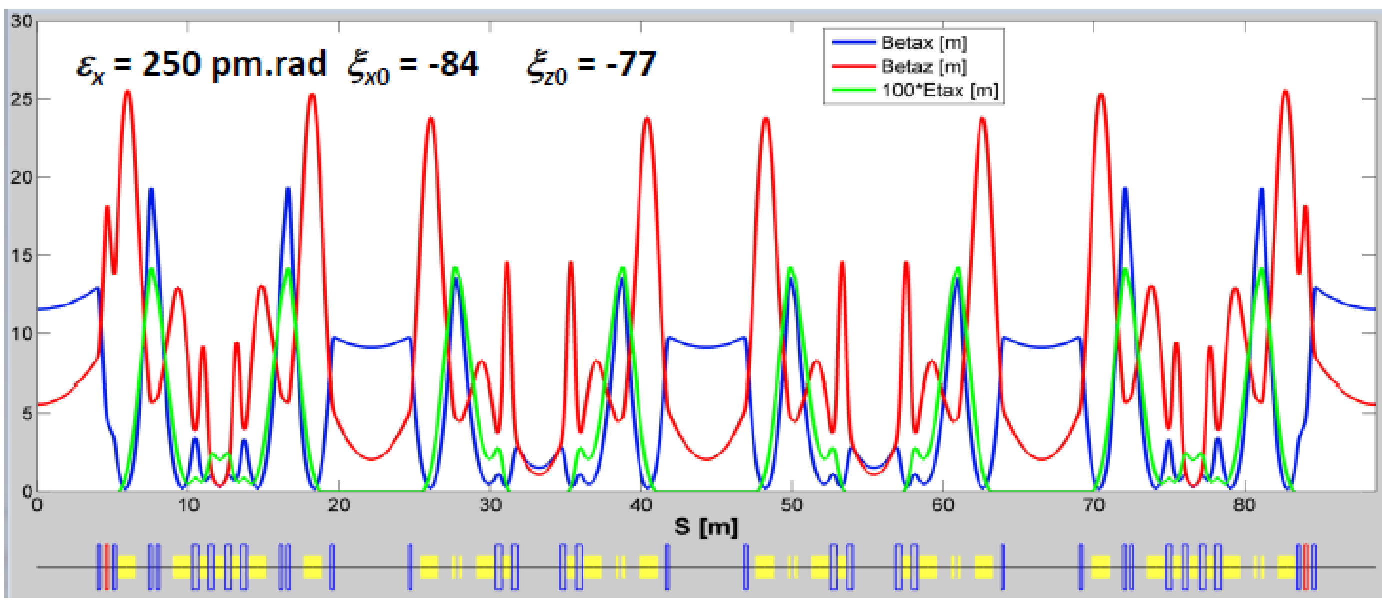


SOLEIL plan (A. Nadji)

Lattice based on 7BA (à la ESRF) and 6BA (à la Diamond)







SOLEIL plan (A. Nadji)

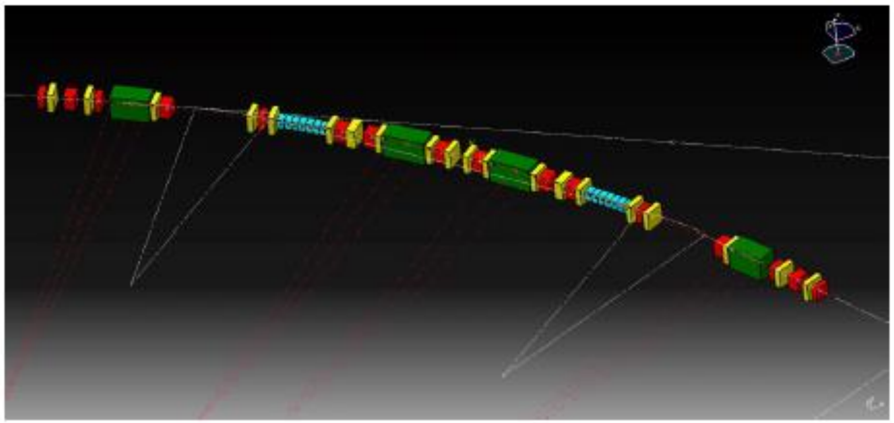
Strategy

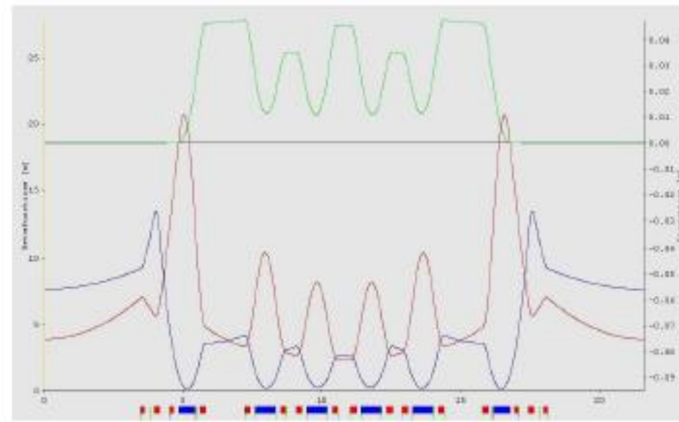
- The Final requirements should derive from future science goals.
- Target date: 2025
- First directions:
  - Higher brilliance and coherence fraction.
  - Short « intense » pulses.

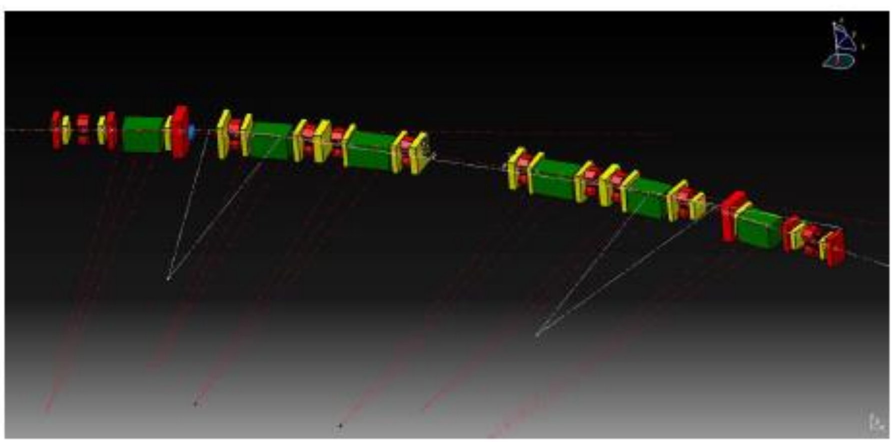
ELETTRA 2.0 plan (E. Karantsoulis)

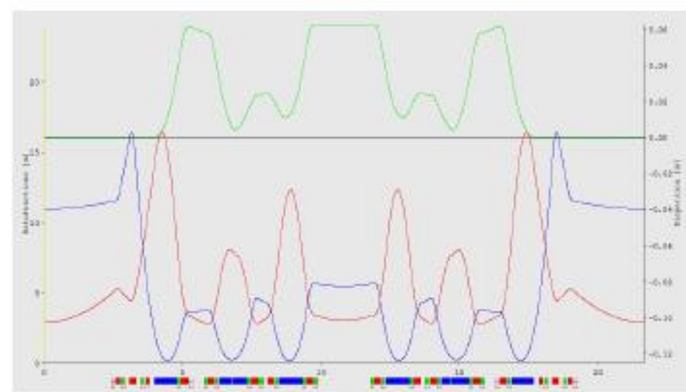
Elettra Sincrotrone Trieste

2 principal configurations





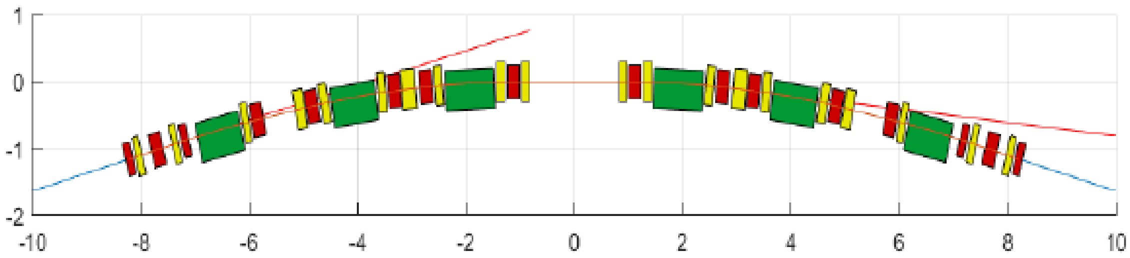




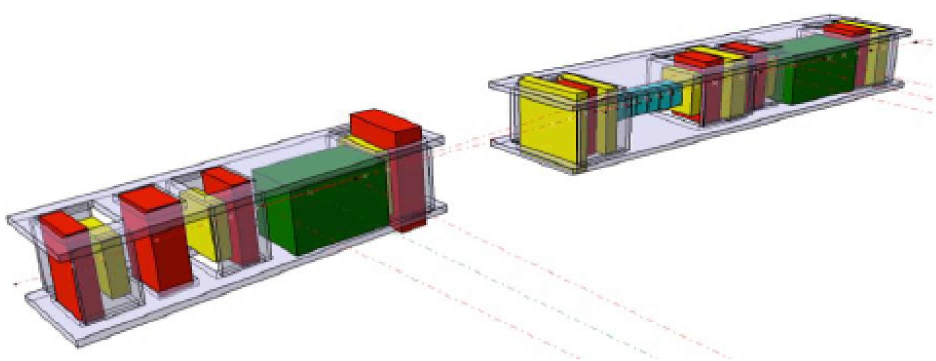
ELETTRA 2.0 plan (E. Karantsoulis)

Elettra
Sincrotrone
Trieste

Physical interference control



Old concrete support bases will not be reused, new girders will be constructed, propose 3D because magnets are thin.

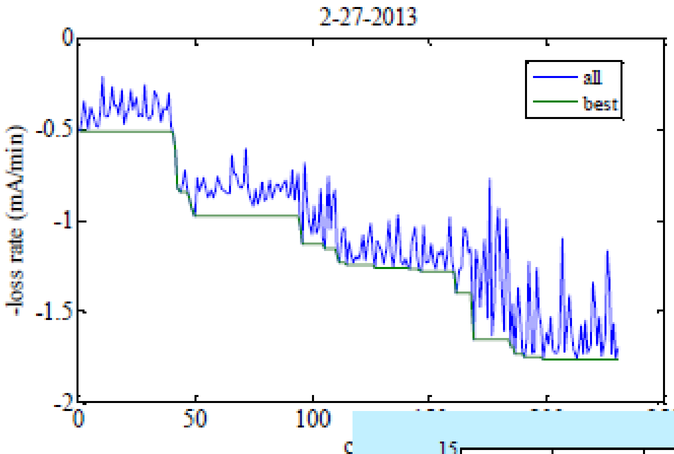


Online dynamics optimisation (X. Huang)

Coupling correction experiments on SPEAR3 with RCDS

SLAC

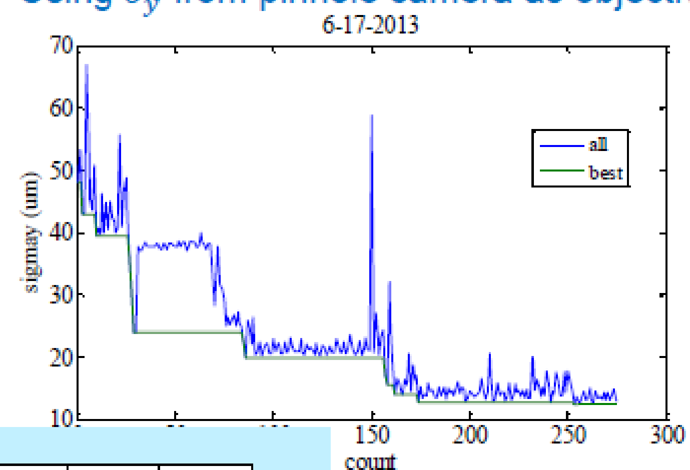
Using loss rate (normalized) as objective



Beam loss rate is m
beam current chang
(no fitting). Noise sig
were taken at 500 m

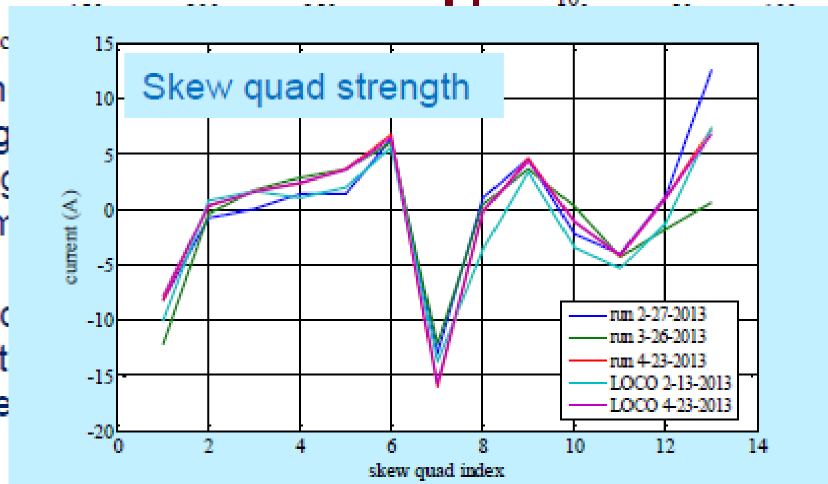
Initially all 13 skew q
At 500 mA, the best
4.6 hrs. This was be
correction (5.2 hrs)

Using σ_y from pinhole camera as objective



at 0.3 micron.
ads were off initially.

a resolution is limited.



Online dynamics optimisation (X. Huang)

Applications of RCDS on real-life problems

SLAC

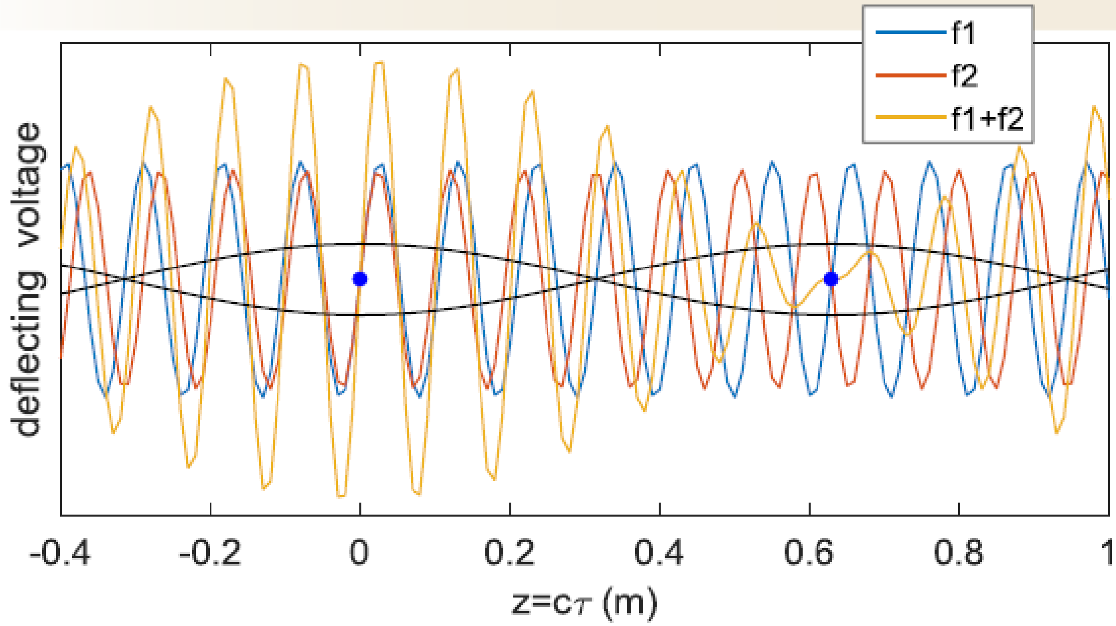
- SPEAR3
  - Kicker bump matching
  - Transport line optics
  - Transport line steering
  - GTL steering and optics
  - Injection efficiency w/ sextupoles — X. Huang, J. Safranek, PRSTAB 18, 084001 (2015)
- LCLS
  - Undulator taper optimization — J. Wu, K. Fang, X. Huang, 2014-2016
- BEPC-II luminosity optimization
  - Steering and coupling — H. Ji, et al, Chinese Physics C 2015 Vol. 39 (12)
  - Interaction point beta
- ESRF — S. M. Liuzzo, et al, IPAC'16, THPMR015
  - beam lifetime w/ sextupoles
  - Injection steering

Two frequency crab cavity scheme (X. Huang)

A. Zholents, NIMA 798, 111 (2015)

The two-frequency crab cavity scheme

SLAC



Two frequencies:

$$f_1 = n f_0,$$

$$f_2 = \left(n + \frac{1}{2}\right) f_0$$

Half of the buckets are tilted, the other half are un-affected.

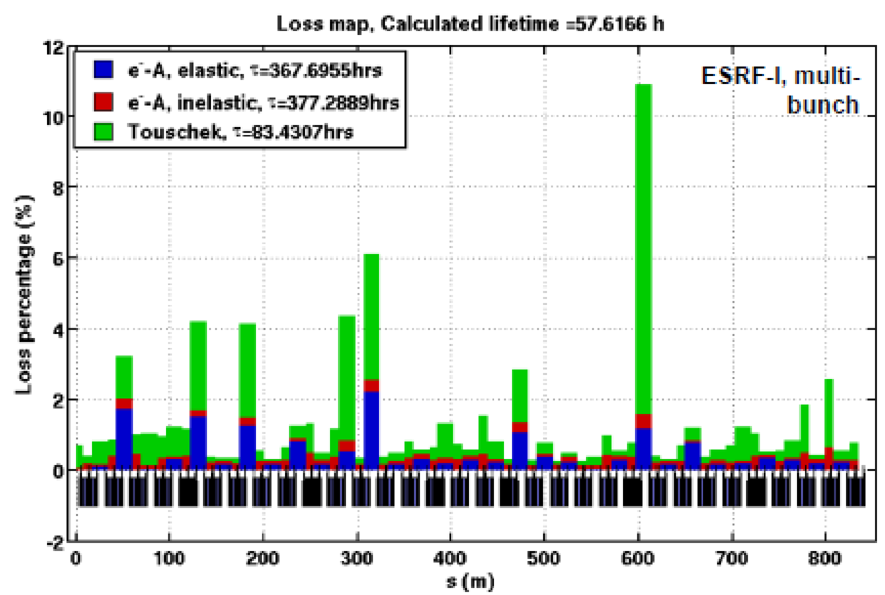
Advantages of the new scheme:

(1) Short pulses are available all around the ring.
(2) No strict phase advance requirement for lattices.
(3) Crab cavities occupy only one straight section (and only one cryostat for SRF)
(4) Both cavities contribute to tilting (less total deflecting voltage required)
(5) Beamlines can easily switch between short pulse mode and regular mode.

ESRF-EBS lifetime/losses analysis (R. Versteegen)

V. VACUUM LOSSES AND CONDITIONING

- Vacuum losses will be dominant over Touschek losses during the commissioning and conditioning of the new machine,
- Following a similar method as for Touschek scattering, scattered electrons can be generated and tracked after colliding with residual gas atoms,
- It includes a detailed pressure profile along the ring, as well as a custom gas composition,
- The losses are determined by
  - the vertical angle acceptance for elastic collisions,
  - by the negative side of the momentum acceptance for the inelastic collisions.



HEPS Injection studies (Z. Duan)

Two RF systems 3rd HC – play with amplitude and phase to manipulate RF buckets for on axis injection and operation
IBS induced parameter changed at injection (Top-Up)

Longitudinal dynamics of a double-RF system

$$H(\phi,\delta;t) = \frac{h_f \omega_0 \eta}{2}\delta^2 + \frac{e\omega_0}{\pi E_b \beta^2}\left[\sum_{i=1}^{N_f} V_f^i \cos(\phi + \phi_f^i) + \frac{h_f}{h_h}\sum_{j=1}^{N_h} V_h^j \cos(\frac{h_h}{h_f} * \phi + \phi_h^j) + \phi\frac{U_0}{e}\right]$$

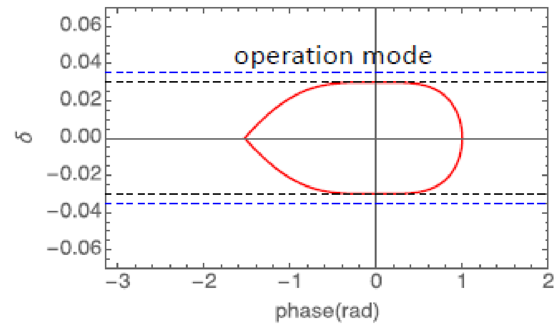
- Fundamental RF system: 166.6MHz, Nf=4
- 3rd harmonic RF system: 499.8MHz, Nh=2
- Same settings for cavities with the same frequency

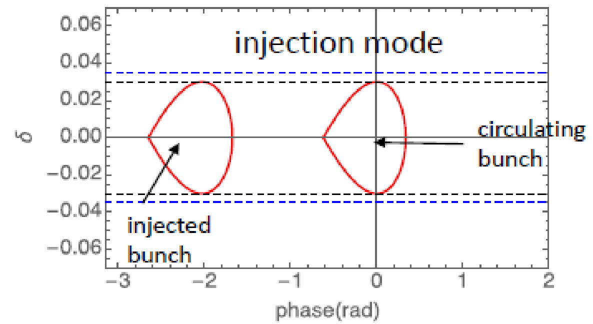
$$V_f = 4V_f^i, \phi_f = \phi_f^i, V_h = 2V_h^i, \phi_h = \phi_h^i$$

- 4 free variables (V_f, φ_f, V_h, φ_h)
- One constraint to fix longitudinal phase of circulating beam relative to the cavities

$$V_f \sin\phi_f + V_h \sin\phi_h = U0$$

- Longitudinal dynamics can be solved to achieve required RF acceptance, in particular, evolution between operation and injection modes.





Semi-analytical approach to nonlinear dynamics (L. Hua Yu)

Write one turn map of Taylor expansion as square matrix

Simplest example of nonlinear map :

$$x = x_0 \cos\mu + p_0 \sin\mu + \epsilon x_0^2 \sin\mu$$
$$p = -x_0 \sin\mu + p_0 \cos\mu + \epsilon x_0^2 \cos\mu,$$

Use $z = x - ip$ and $z^* = x + ip$

$$z = e^{i\mu} z_0 - \frac{i}{4}\epsilon e^{i\mu} z_0^2 - \frac{i}{2}\epsilon e^{i\mu} z_0 z_0^* - \frac{i}{4}\epsilon e^{i\mu} z_0^{*2}$$
$$z^* = e^{-i\mu} z_0^* + \frac{i}{4}\epsilon e^{-i\mu} z_0^2 + \frac{i}{2}\epsilon e^{-i\mu} z_0 z_0^* + \frac{i}{4}\epsilon e^{-i\mu} z_0^{*2}$$
$$z^2 = e^{2i\mu} z_0^2 - \frac{i}{2}\epsilon e^{2i\mu} z_0^3 - i\epsilon e^{2i\mu} z_0^2 z_0^* - \frac{i}{2}\epsilon e^{2i\mu} z_0 z_0^{*2}$$
$$zz^* = z_0 z_0^* + \frac{i}{4}\epsilon z_0^3 + \frac{i}{4}\epsilon z_0^2 z_0^* - \frac{i}{4}\epsilon z_0 z_0^{*2} - \frac{i}{4}\epsilon z_0^{*3},$$
$$z^{*2} = e^{-2i\mu} z_0^{*2} + \frac{i\epsilon}{2} e^{-2i\mu} z_0^2 z_0^* + i\epsilon e^{-2i\mu} z_0 z_0^{*2} + \frac{i\epsilon}{2} e^{-2i\mu} z_0^{*3}$$
$$z^3 = e^{3i\mu} z_0^3$$
$$\ldots$$
$$z^{*3} = e^{-3i\mu} z_0^{*3}$$

$$\tilde{Z} = (1, z, z^*, z^2, zz^*, z^{*2}, z^3, z^2 z^*, zz^{*2}, z^{*3}). \longrightarrow \quad Z = MZ_0,$$

Fast computation of nonlinear dynamic quantities (detuning, action variations, …)

Conclusions

Many excellent talks (cannot fit in this short summary)

MAX IV well in its commissioning, SIRIUS and ESRF-EBS being built

Many projects in design phase. Slowly but steadily gaining approval

APS–U CD1 February 16
ALS–U CD0 September 16

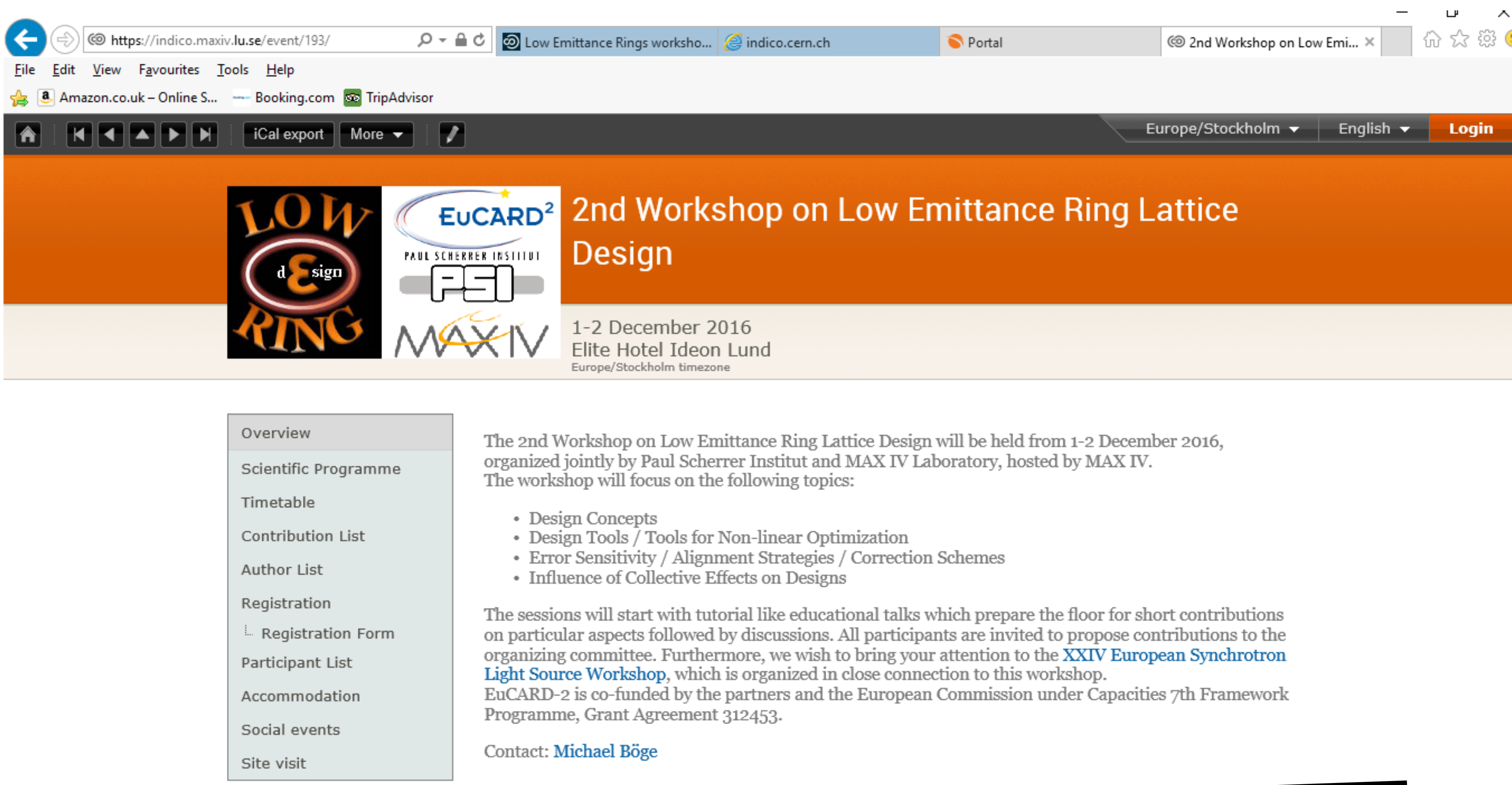
Optimisation !

from lattice design to operation

LERD topical workshop in Lund 1-2 December

https://indico.maxiv.lu.se/event/193/

Topical workshop on lattice design
Lund 1-2 December 2016



Thank you !