Introduction to Synchrotron Light Sources

Sverker Werin
MAX IV Laboratory
Lund University

Sometimes you wonder why?

http://www.ehow.com/facts_7459682_exhaust-smell-like-rotten-eggs_.html

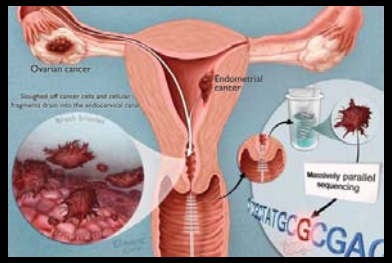
Sometimes you wonder think if…!

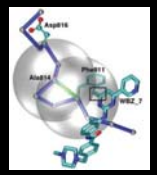
http://www.connectedinternet.co.uk/2011/07/12/increase-mobile-battery-life/

Sometimes you wonder why 100 GB and not 5 TB?

http://www.gizmag.com/go/4547/

Sometimes you wonder, why not just a pill?





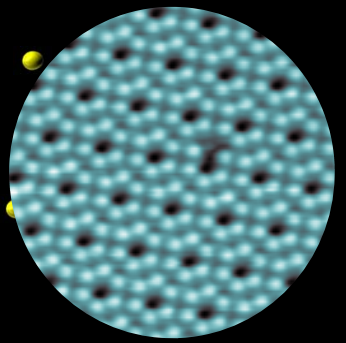
http://www.dagensmedicin.se/vetenskap/kvinnohalsa/cellprov-avslojade-aggstockscancer/

http://www.sciencedaily.com/releases/2007/05/070501115127.htm

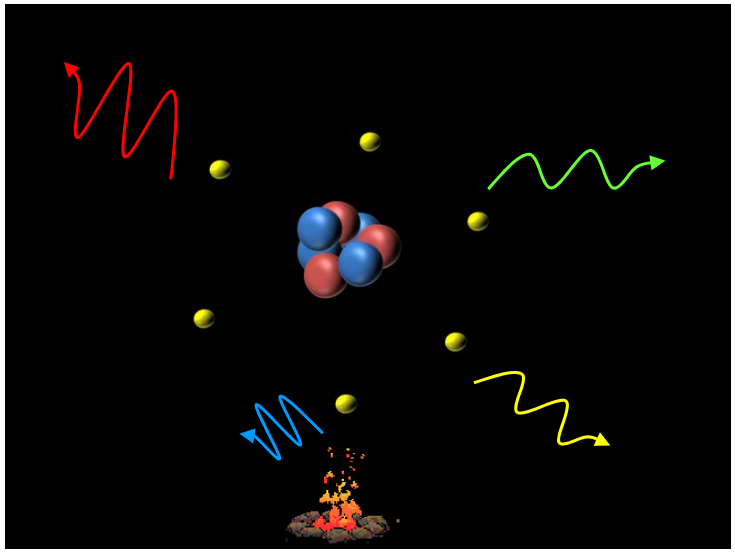
Investigate and see!

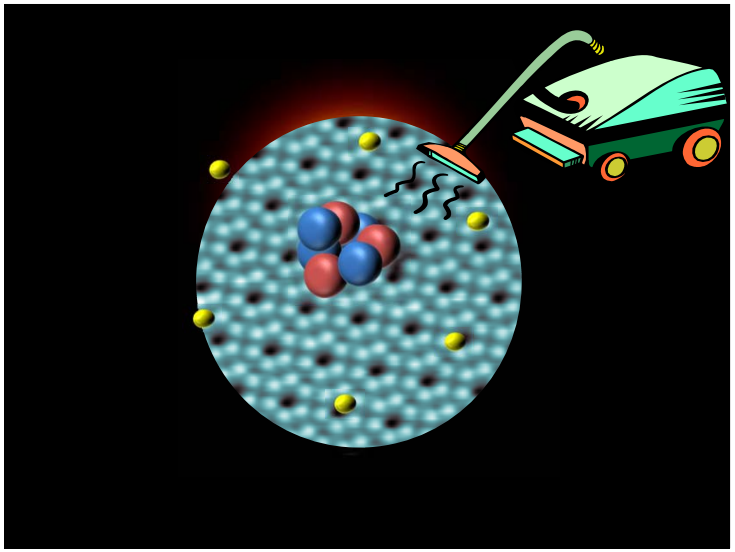
http://gracespace.org.uk/wp-content/uploads/2010/05/nicole-katano-explore-child-in-the-rain.jpg
http://www.petershamaog.org.au/index.php?id=53

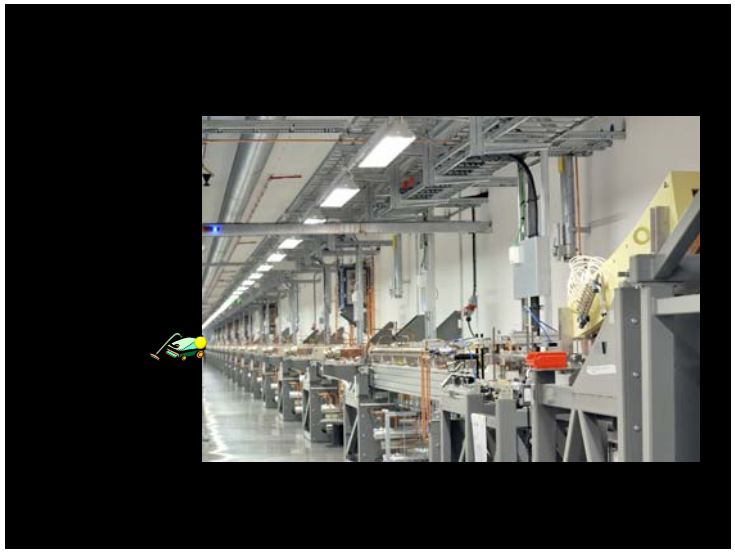
http://academic.greensboroday.org

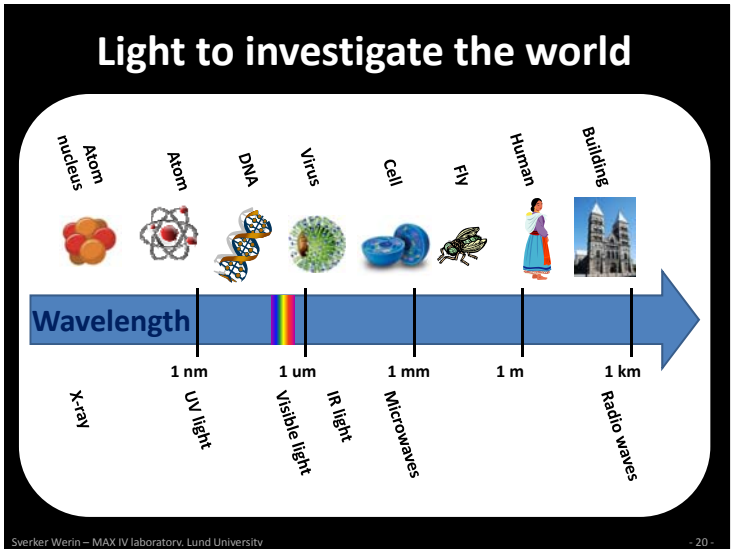


http://academic.greensboroday.org








Light to investigate the world
Atom nucleus
Atom
DNA
Virus
Cell
Fly
Human
Building
Wavelength
1 nm
1 um
1 mm
1 m
1 km
X-ray
UV light
Visible light
IR light
Microwaves
Radio waves
Sverker Werin – MAX IV laboratory, Lund University
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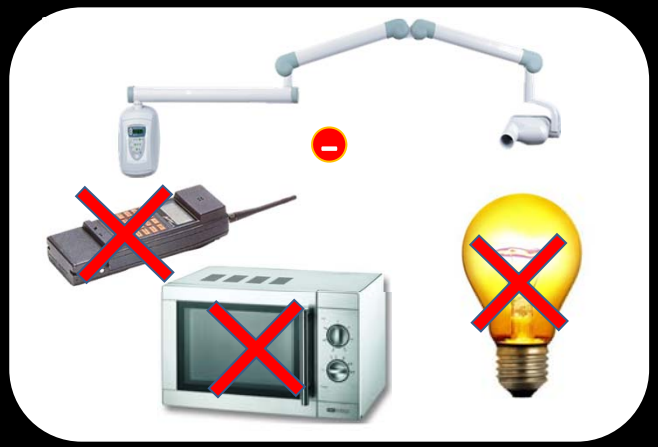
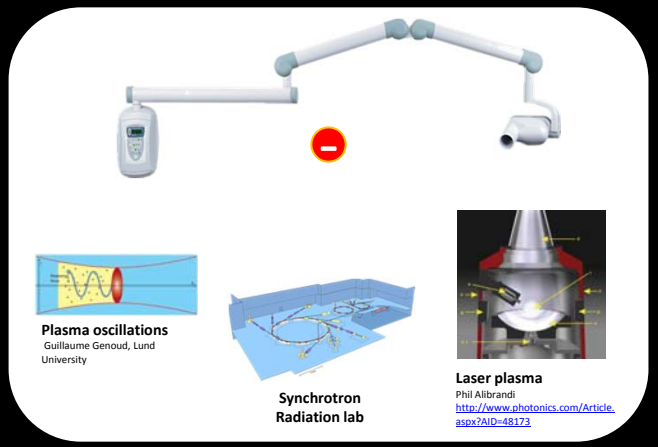
Light sources around us



Light sources around us

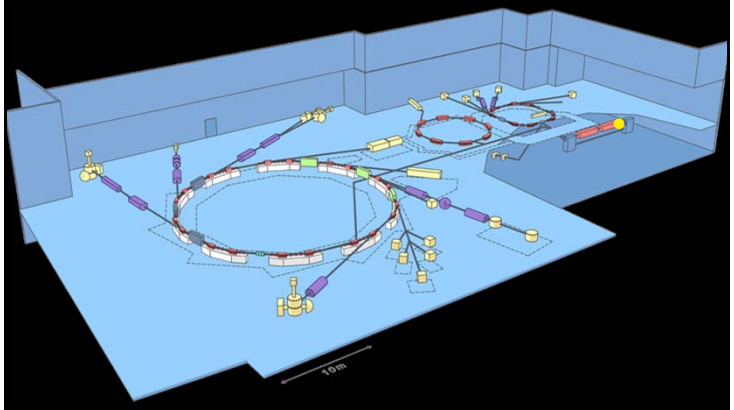


Plasma oscillations
Guillaume Genoud, Lund University

Synchrotron Radiation lab

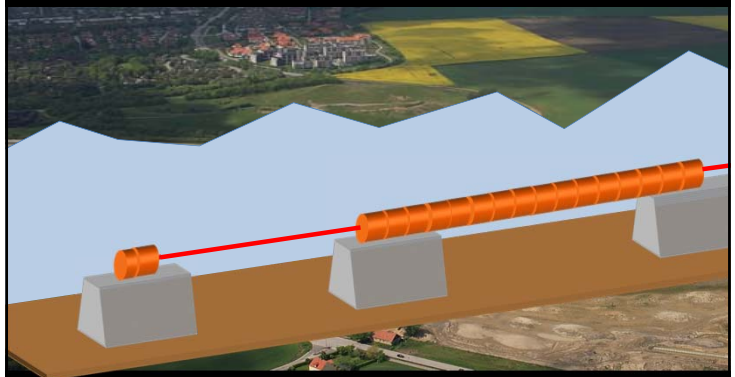
Laser plasma
Phil Alibrandi
http://www.photonics.com/Article.aspx?AID=48173

Synchrotron Laboratory (MAX-lab)

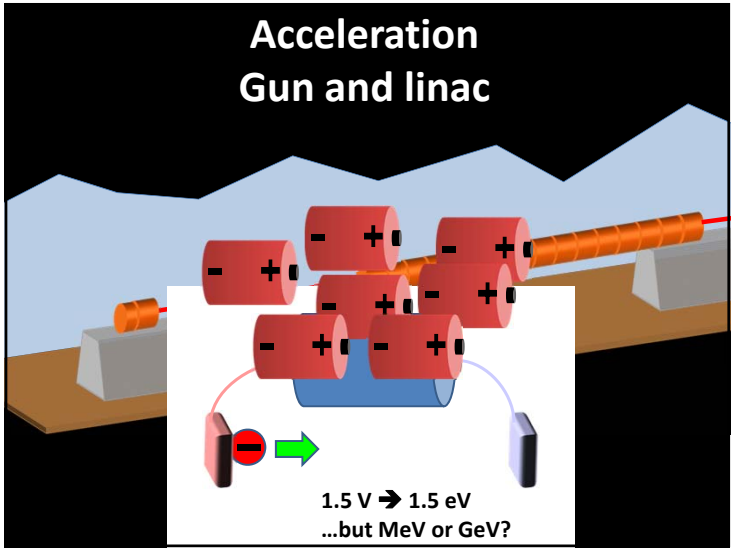


The pieces of MAX IV

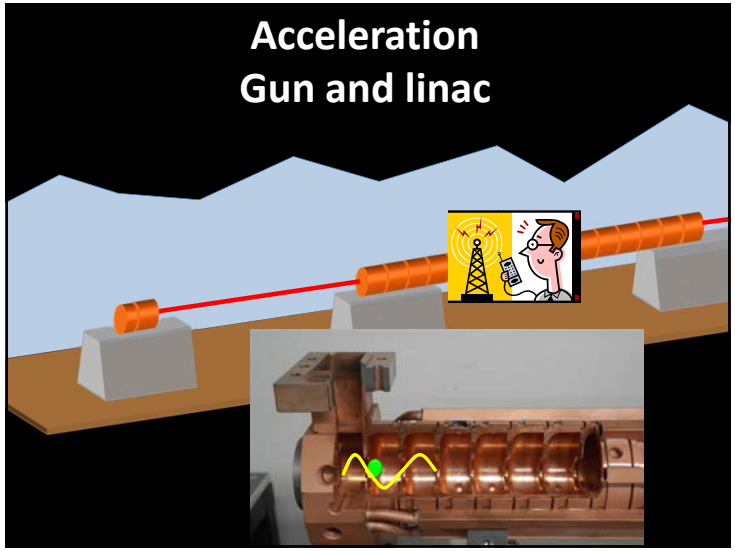
Acceleration



Acceleration
Gun and linac



Acceleration
Gun and linac

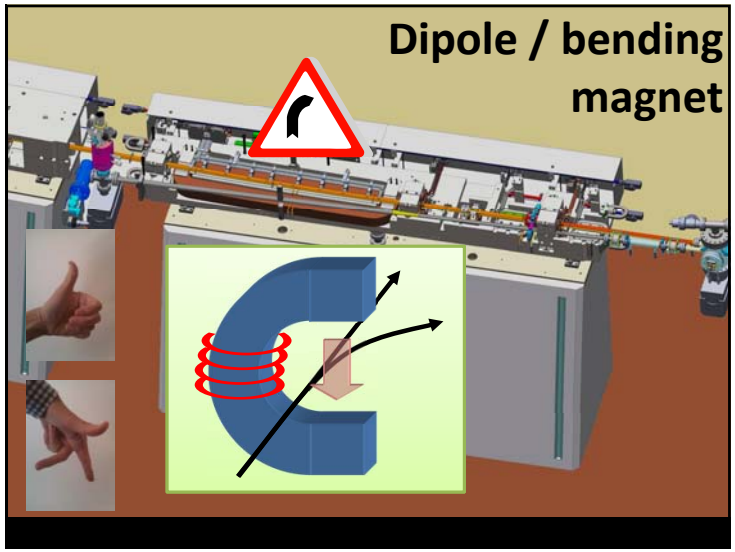


Linear accelerator (MAX IV)

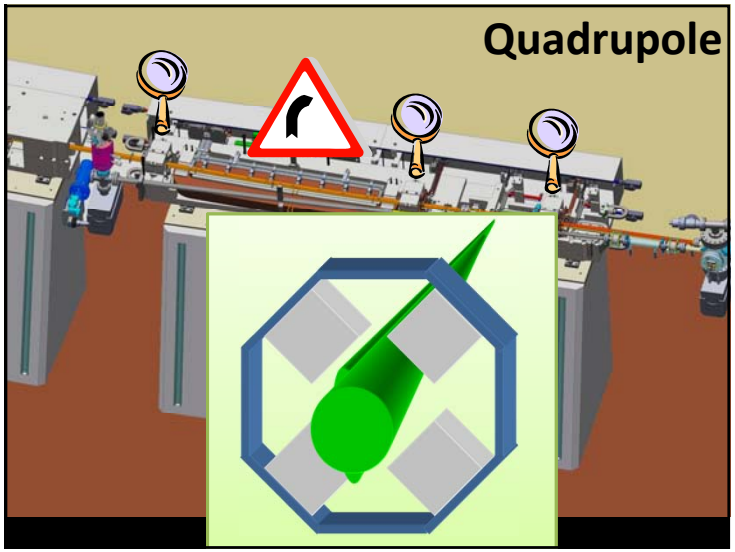
Inside the ring building

Styra around the ring

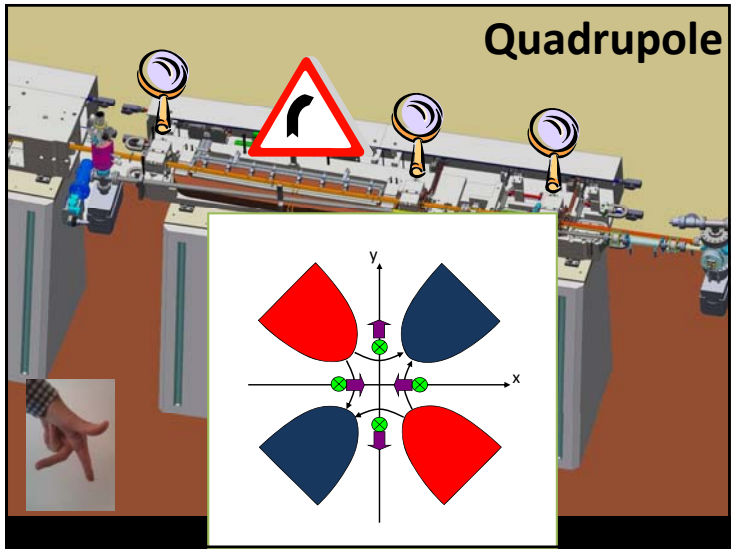
Dipole / bending magnet

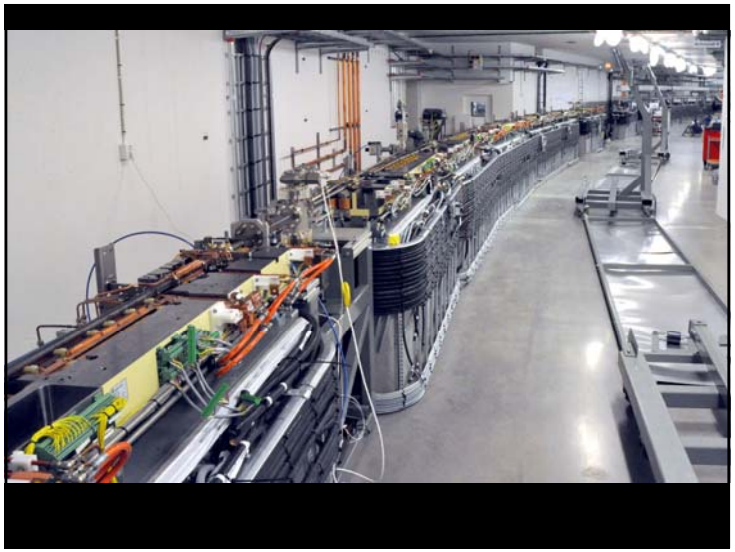


Quadrupole



Quadrupole

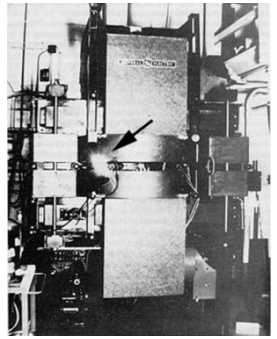




Light and undulators

First discovery of SR 1947

"On April 24, Langmuir and I were running the machine … we asked the technician to observe with a mirror around the protective concrete wall. " (Herb Pollock)



General Electric Research Laboratory, Schenectady, NY, US

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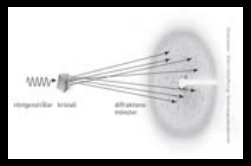
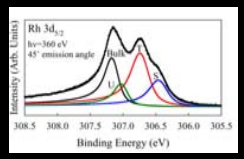
Techniques at a beam line

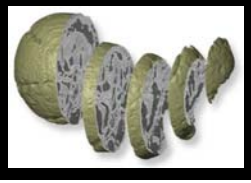
Scattering



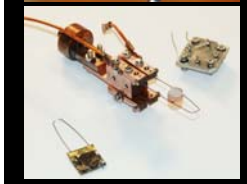


Spectroscopy

Imageing



Samples

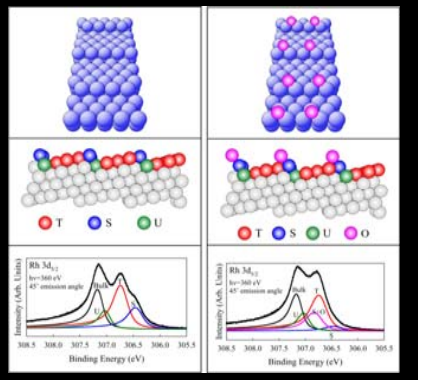


Catalyser (rhodium)

Geometry and chemical bonds with the help of photo electron spectroscopy

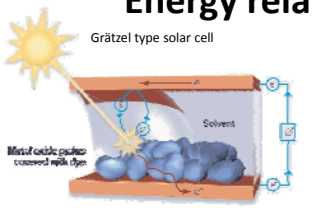
Clean rhodium-crystal surface

Some oxygen added

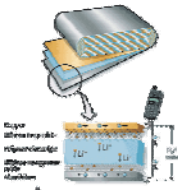


Energy related research

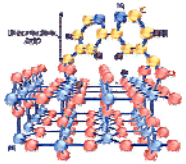
Grätzel type solar cell



Rechargeable Li batteries

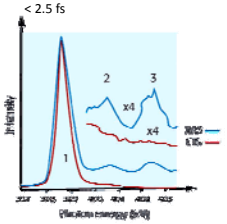


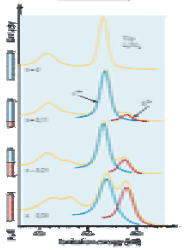
Bonding of dye molecules



J. Schnadt et al.

Probing charge transfer times
< 2.5 fs



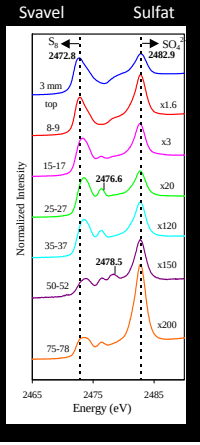


What happens with the wood in the Vasa ship?

Photo: Hans Hammarskiöld, the Vasa Museum

What happens with the wood in the Vasa ship?

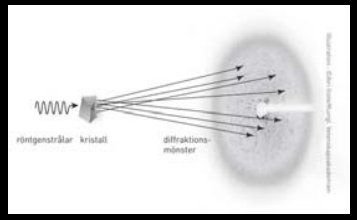
Svavel XANES spektra från *Vasa*



Nature **2002**, *415*, 893-897
M. Sandström *et al*.

Drugs (ribosome in a bakteria)

2009 Nobel price in Chemistry
Venkatraman Ramakrishnan, Thomas A. Steitz och Ada E. Yonath



0th and 1st generation light sources

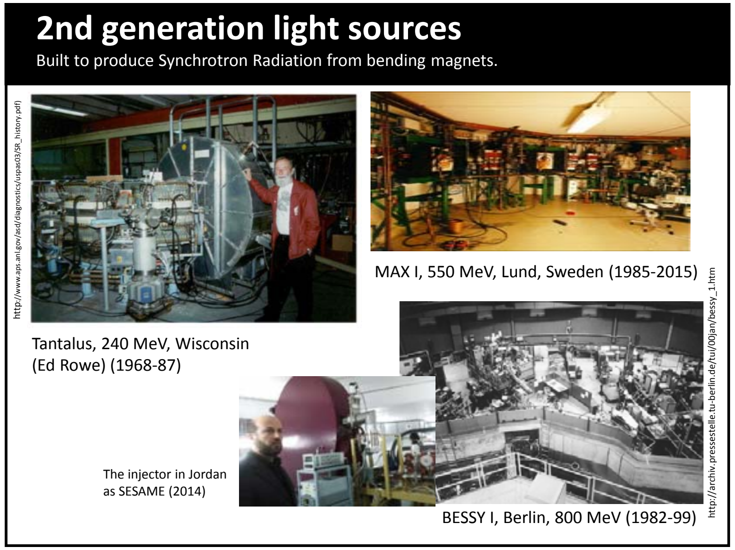
Parasitic machines, built to do something else.

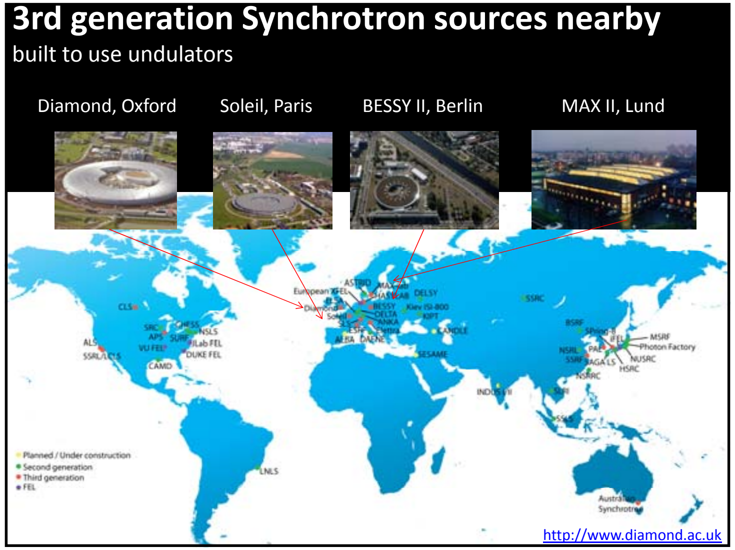
DESY 7.4 GeV electron synchrotron
1964 electron positron collider
1967 SR production as a side effect

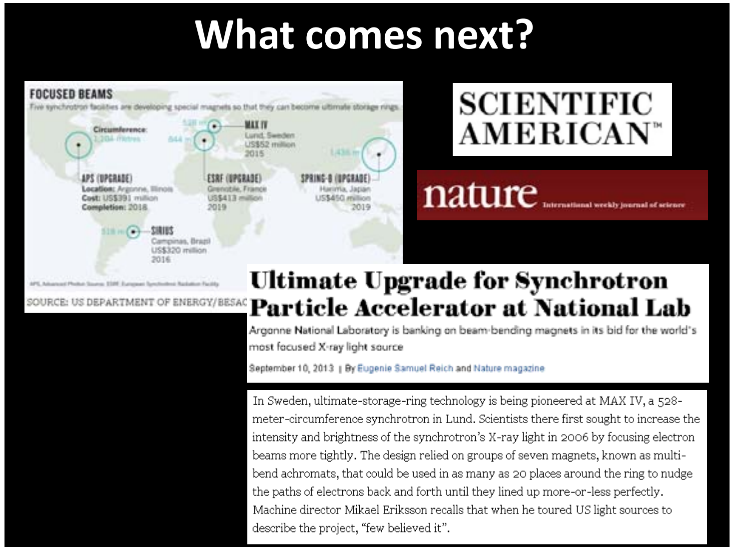
Where is DESY? (Erased from history?)

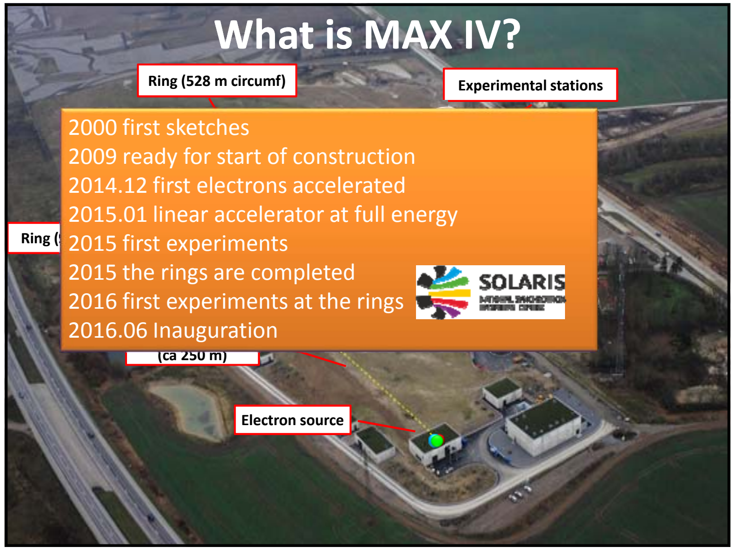
ACO in Orsay, Paris
Electron-positron collider
500 MeV

http://www.sciencesaco.fr/


2nd generation light sources
Built to produce Synchrotron Radiation from bending magnets.
MAX I, 550 MeV, Lund, Sweden (1985-2015)
Tantalus, 240 MeV, Wisconsin
(Ed Rowe) (1968-87)
The injector in Jordan
as SESAME (2014)
BESSY I, Berlin, 800 MeV (1982-99)
http://archiv.pressestelle.tu-berlin.de/tui/00jan/bessy_1.htm

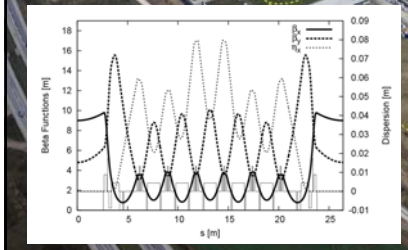

3rd generation Synchrotron sources nearby
built to use undulators
Diamond, Oxford
Soleil, Paris
BESSY II, Berlin
MAX II, Lund
Planned / Under construction
Second generation
Third generation
FEL
http://www.diamond.ac.uk

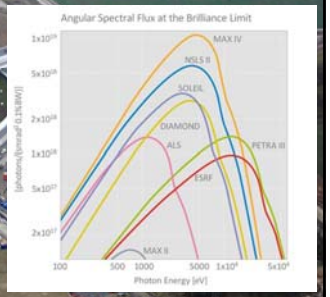

What comes next?
FOCUSED BEAMS
SOURCE: US DEPARTMENT OF ENERGY/BESAC
SCIENTIFIC AMERICAN™
nature
Ultimate Upgrade for Synchrotron Particle Accelerator at National Lab
Argonne National Laboratory is banking on beam-bending magnets in its bid for the world's most focused X-ray light source
September 10, 2013 | By Eugenie Samuel Reich and Nature magazine
In Sweden, ultimate-storage-ring technology is being pioneered at MAX IV, a 528-meter-circumference synchrotron in Lund. Scientists there first sought to increase the intensity and brightness of the synchrotron's X-ray light in 2006 by focusing electron beams more tightly. The design relied on groups of seven magnets, known as multi-bend achromats, that could be used in as many as 20 places around the ring to nudge the paths of electrons back and forth until they lined up more-or-less perfectly. Machine director Mikael Eriksson recalls that when he toured US light sources to describe the project, "few believed it".


What is MAX IV?
Ring (528 m circumf)
Experimental stations
2000 first sketches
2009 ready for start of construction
2014.12 first electrons accelerated
2015.01 linear accelerator at full energy
2015 first experiments
2015 the rings are completed
2016 first experiments at the rings
2016.06 Inauguration
SOLARIS
(ca 250 m)
Electron source

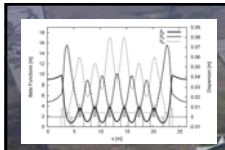
What is MAX IV?

Circumference (m)	528
Nr of straight sections	20
Injection	full energy, top-up
Stored current (mA)	500
Horizontal emittance (nm rad)	0.2 - 0.3
Vertical emittance (nm rad)	< 0.008
Horizontal beam size (σ µm)	42- - 52
Vertical beam size (σ µm)	< 6





How?



- 7 BA
- Small emittance
- Small beam
- Small dispersion
- Sextupoles and chromaticity corr.?
- High density
- Small vacuum chamber
- SR ports?
- Small magnets
- Stretch the beam
- Pumping?
- Instabilities (?)
- 100 MHz RF
- NEG coating
- Harmonic cavities
- Short pulses @ linac