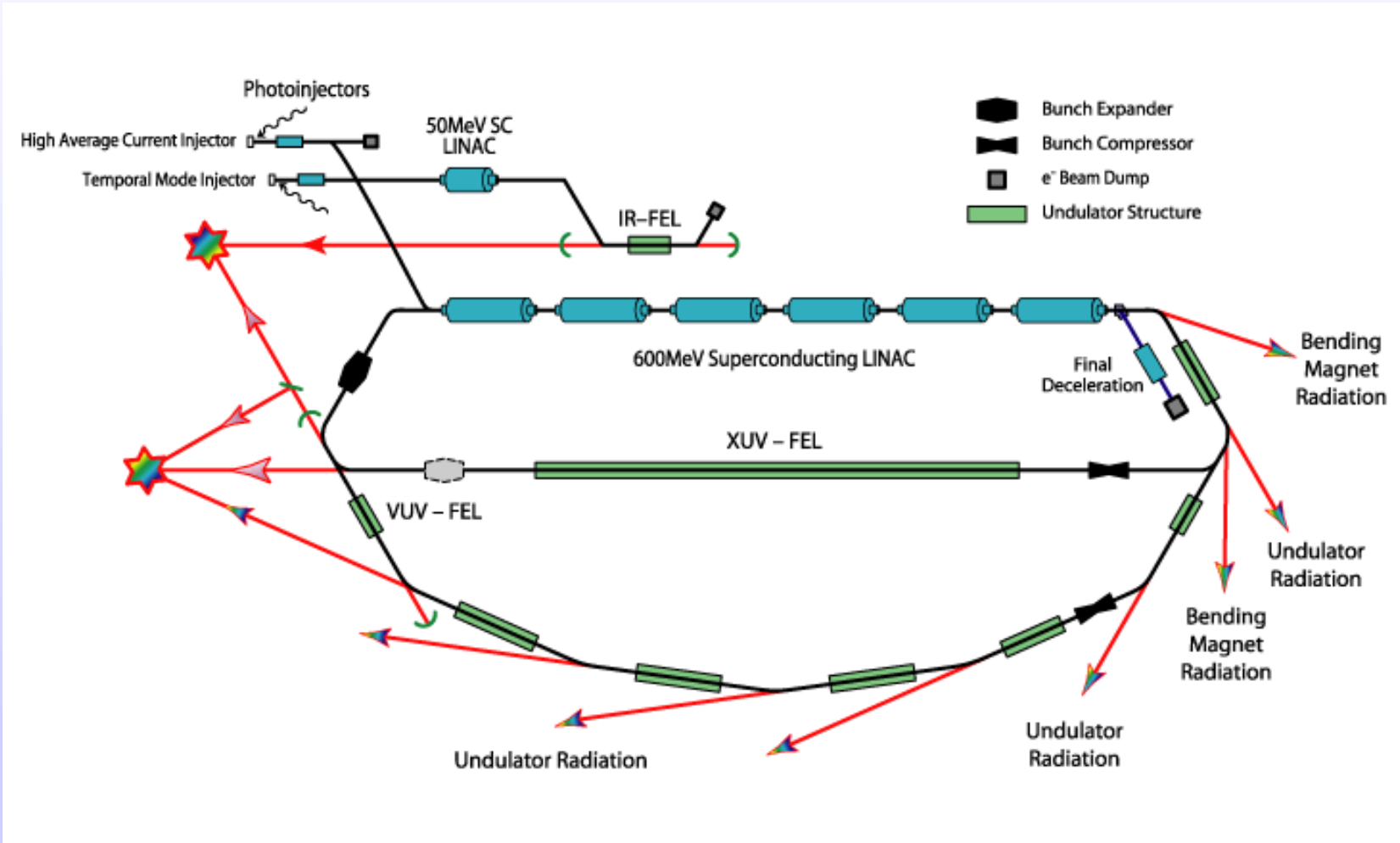
4GLS

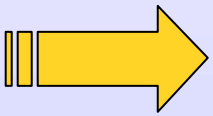
Plan

- Overview of the project
  - accelerator
  - science
- Update since June 2001
- Next steps

A suite of light sources



Why is an energy recovery linac so important?



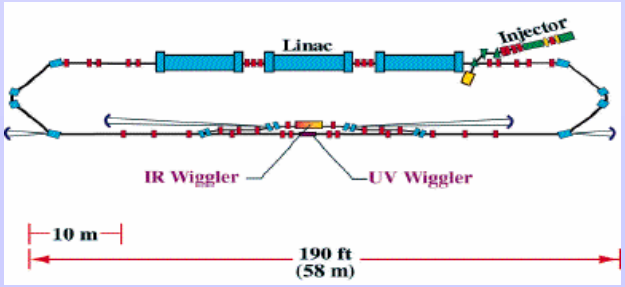
Because it allows you to take a MAJOR step beyond the stringent requirements and limitations of storage ring technology ….

The single pass nature of the ERL gives rise to a number of very important advantages both in terms of the accelerator and the radiation produced.

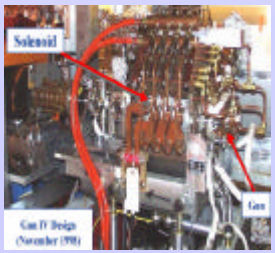
The benefits...

- short pulses - femtosecond regime
- control of pulse structure - pulse tailoring
- effectively infinite beam lifetimes
- larger peak currents
- symmetrical beam and small emittance

In addition, the ERL approach combined with high brightness injectors are ideal for free electron lasers, FELs.



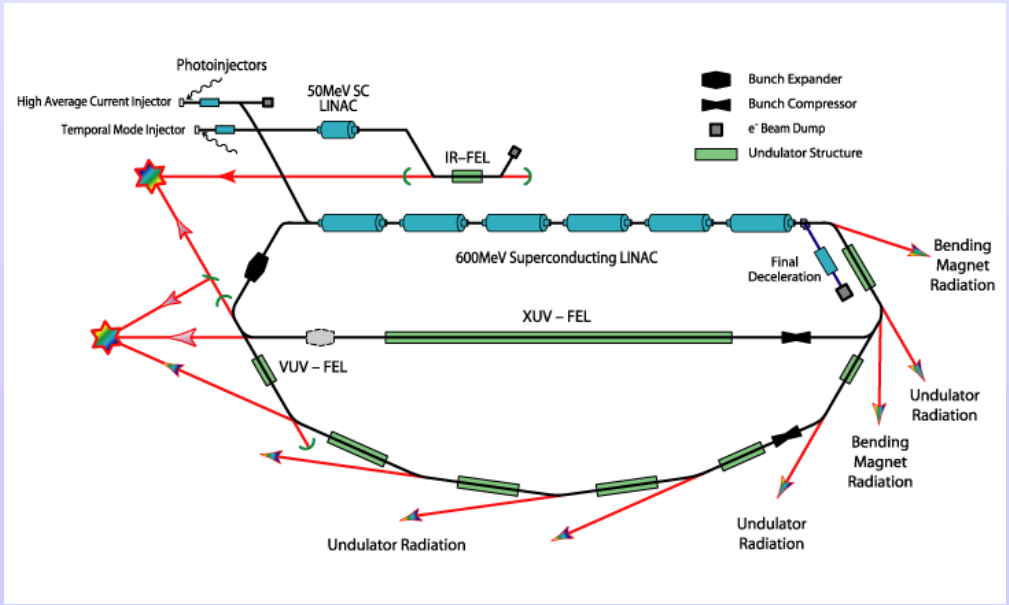
ERL Ring development JLAB



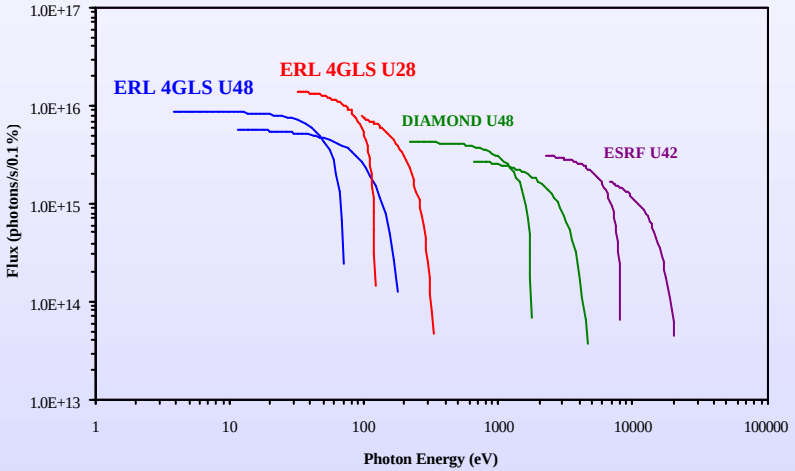
Photoinjector: The BNL Deep UV FEL project

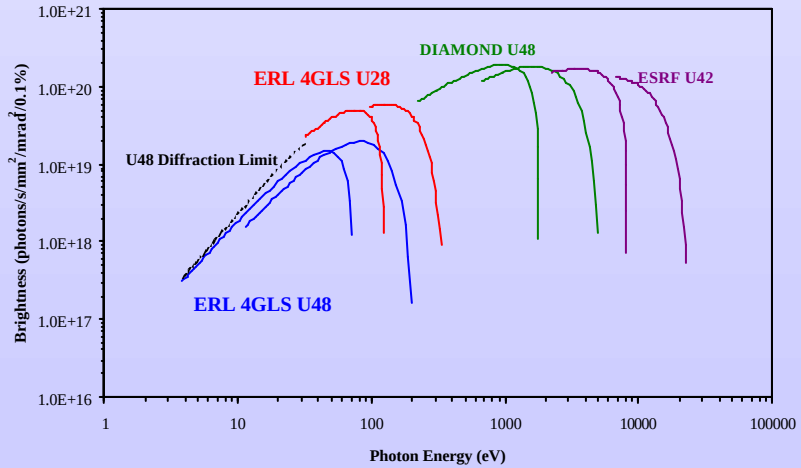
Not a storage ring - ERL

- **spontaneous emission sources**
  undulators and bending magnets
- **stimulated emission sources**
  free electron lasers



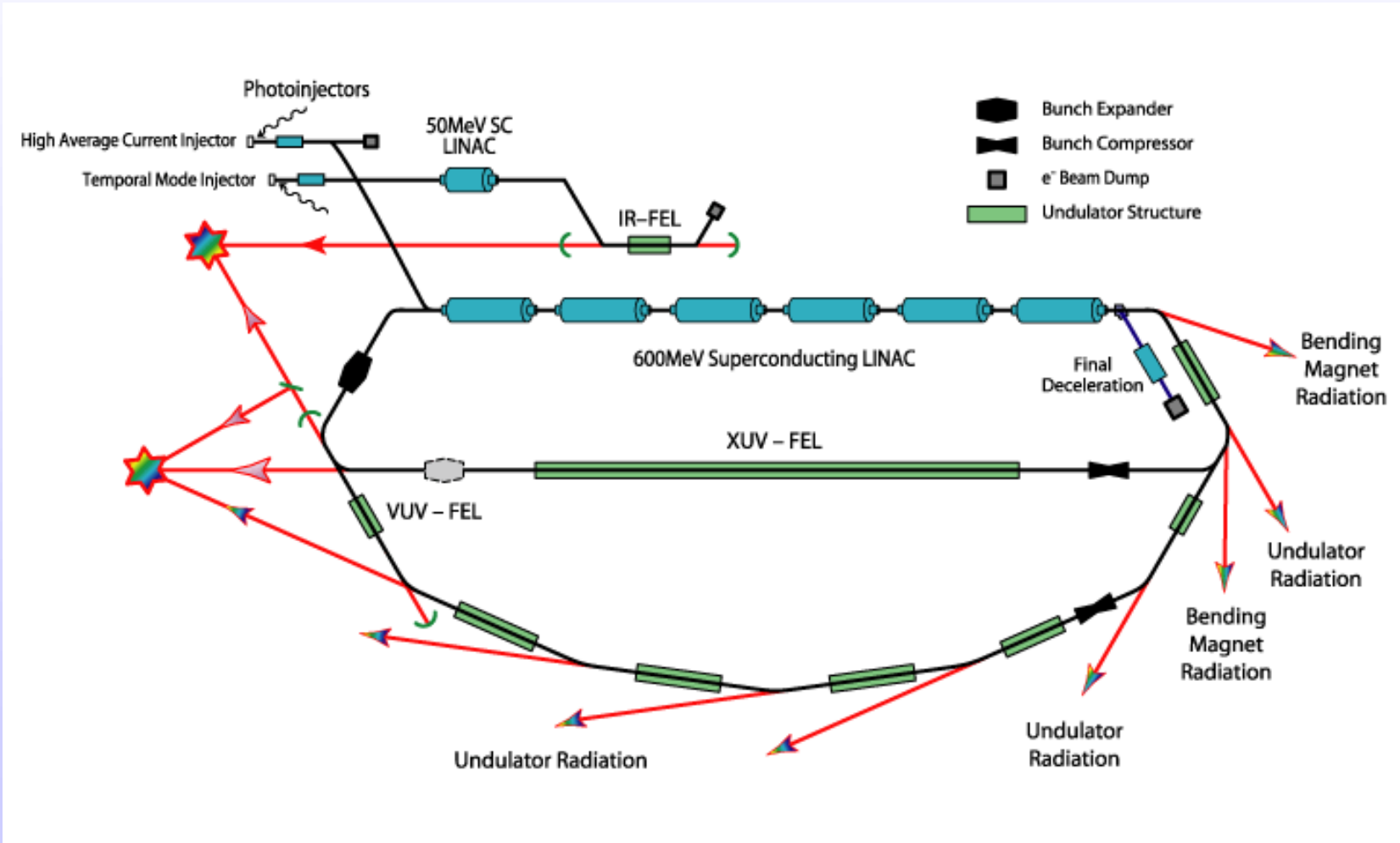
4GLS undulator sources





- Optimised for high flux and brightness, in the energy range 4-100 eV.
- Up to 500-600 eV available in the higher harmonics.
- Complements Diamond by reaching to lower photon energy and delivering an order of magnitude better brightness in the sub-100 eV energy range.

4GLS FELs


Photoinjectors
High Average Current Injector
Temporal Mode Injector
50MeV SC LINAC
IR–FEL
600MeV Superconducting LINAC
Final Deceleration
XUV – FEL
VUV – FEL
Bunch Expander
Bunch Compressor
e⁻ Beam Dump
Undulator Structure
Bending Magnet Radiation
Undulator Radiation
Bending Magnet Radiation
Undulator Radiation
Undulator Radiation

4GLS electron energy 600MeV

Cavity based VUV-FEL

- sub ps pulses
- repetition rate, calcs for 6.25 MHz
- photons 3-10 eV broad tunability
  up to 25 eV possible with restricted tunability
- peak brightness 10^{26} photons/(s mm^2 mr^2 0.1%BP)
- photons per pulse ~10^{13}

XUV-FEL

- fundamental 10-100 eV
- seeded, 10s fs long, 10s μs separation
- peak power 1 mJ per pulse
- peak brightness 10^{29} photons/(s mm^2 mrad^2 laser BP)
- photons per pulse ~10^{14}

IR-FEL - electron energy *ca.*50MeV

IR-FEL 3-75μm

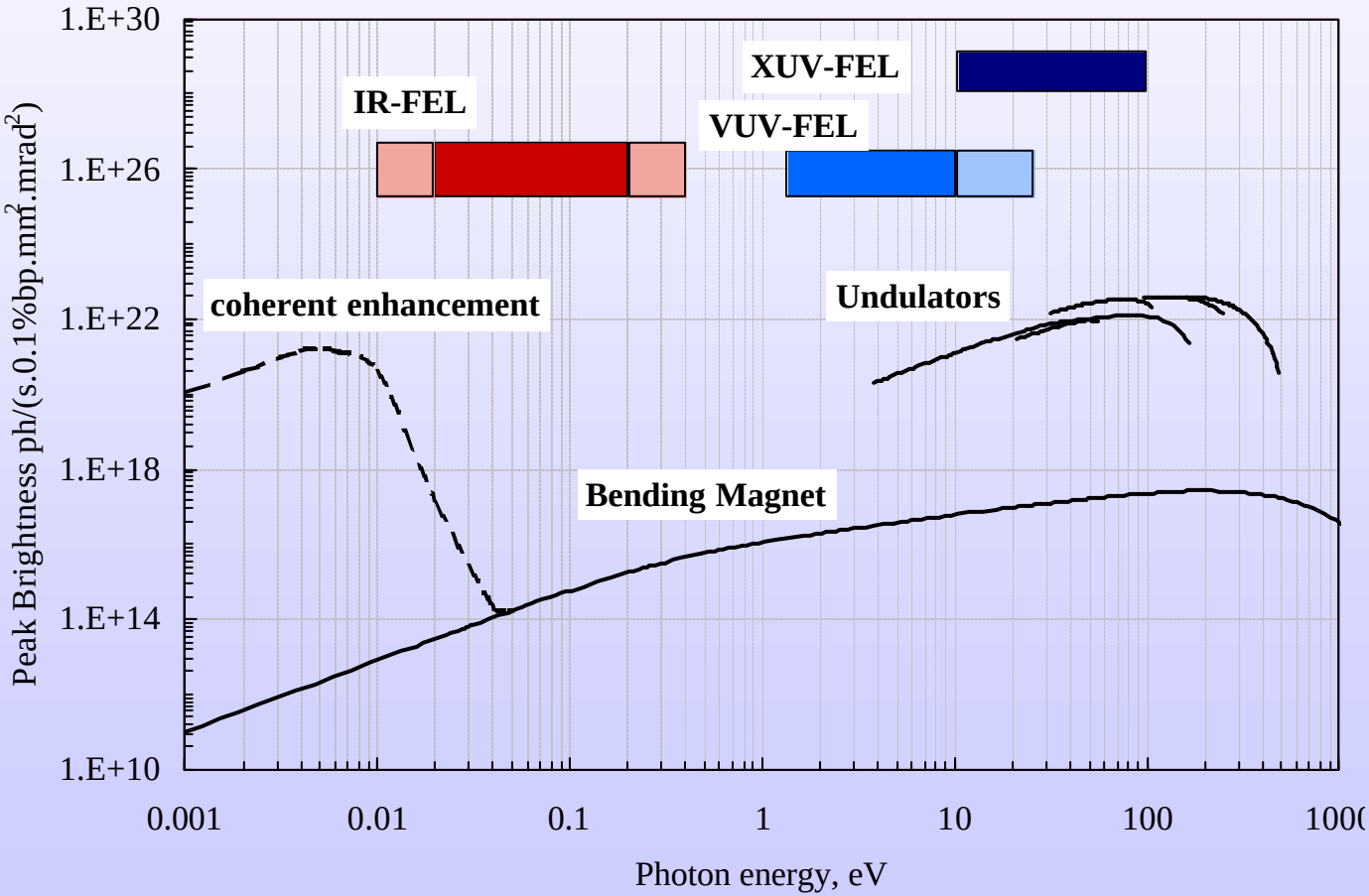
Photocathode and superconducting linac, therefore

- much greater average current
- better energy stability
- shorter pulse lengths

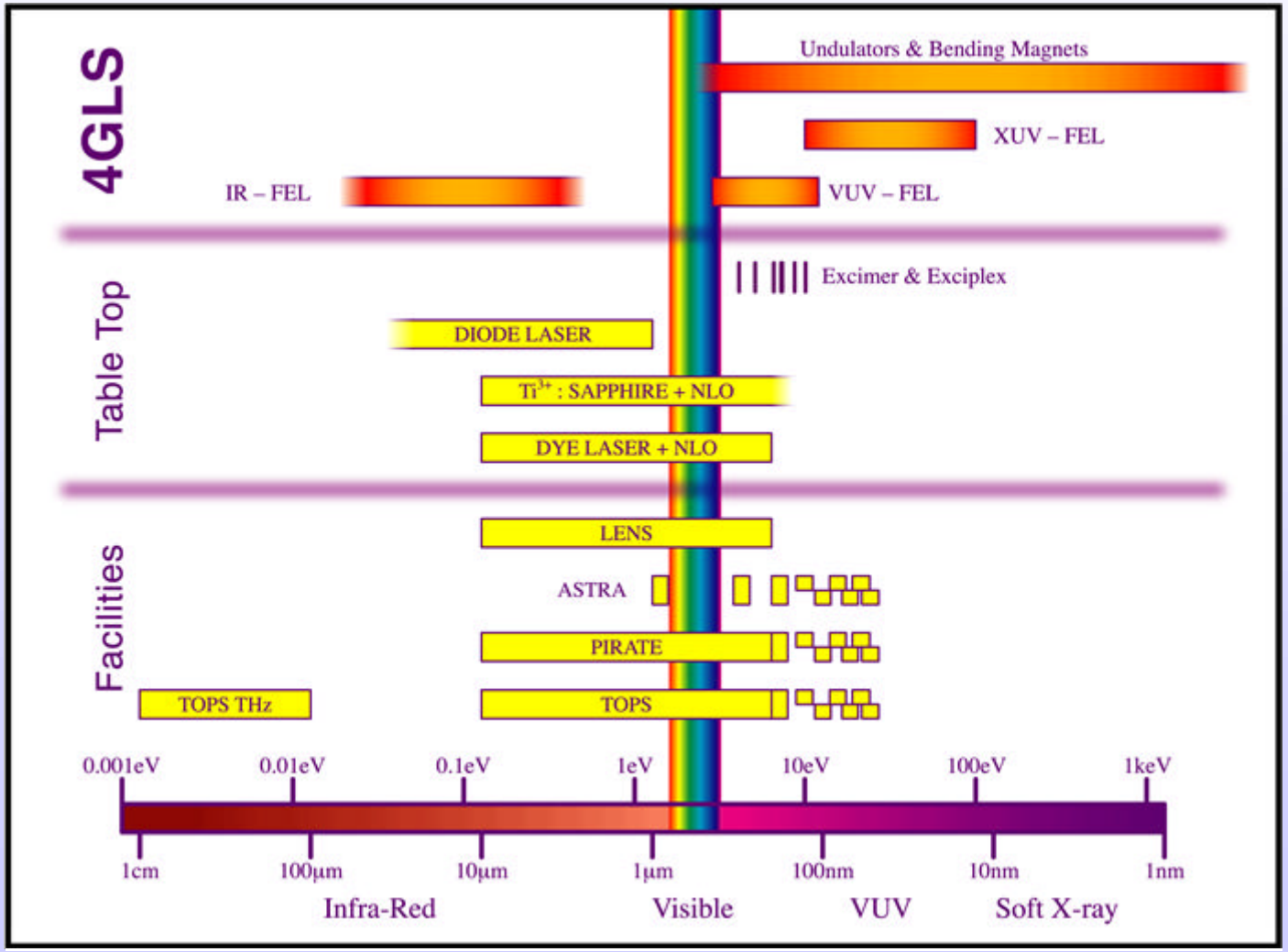
better than *anything* around in Europe

- synchronisation

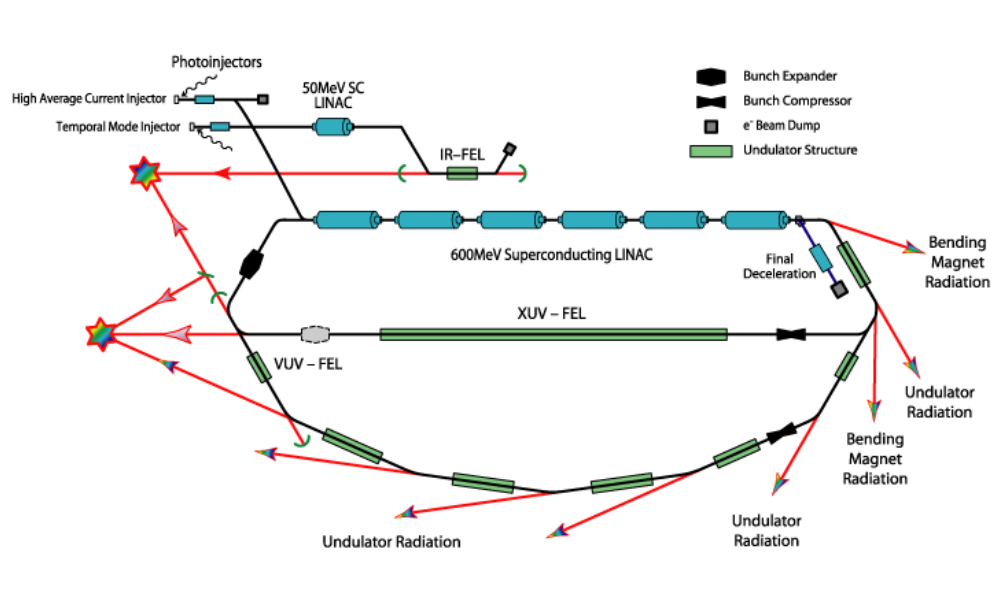
4GLS FELs


1.E+30
1.E+26
1.E+22
1.E+18
1.E+14
1.E+10
Peak Brightness ph/(s.0.1%bp.mm².mrad²)
0.001
0.01
0.1
1
10
100
Photon energy, eV
IR-FEL
XUV-FEL
VUV-FEL
coherent enhancement
Undulators
Bending Magnet

Complementarity with table-top lasers



4GLS combines superconducting ERL, SR and FEL technology in a multi-source facility



- ***'It incorporates the latest advances in machine design and builds upon those innovations to deliver a robust, flexible and cost-effective design.'***

- ***'This project not only provides exceptional value, the flexibility of the design ensures that the facility can continue to grow as technological innovations occur'***

Accelerator challenges ...

- High current target, 100mA, for spontaneous SR users (injector and SC linac)
- Integration of a range of sources that are required to operate as a user facility
- Synchronisation of individual sources to levels appropriate for the pump-probe experiments

4GLS

4GLS offers …

- brightness - XUV-FEL peak brightness $>10^7$ times that of 3rd generation sources Diamond/Soleil spontaneous peak brightness
- short pulses - down to femtosecond regime
- control of pulse structure
- coherence
- effectively infinite beam lifetimes
- multi-user access

and

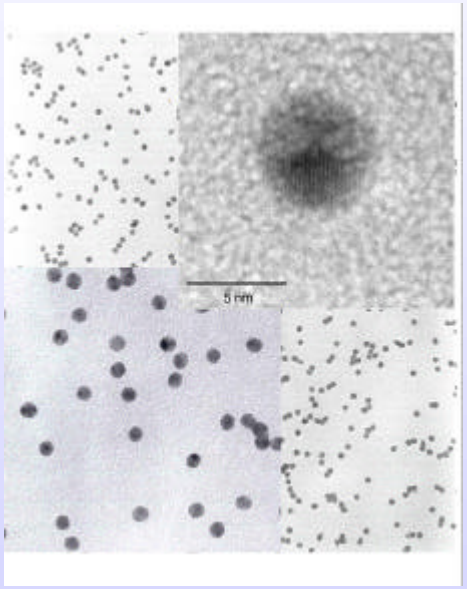
- unique experimental potential

4GLS

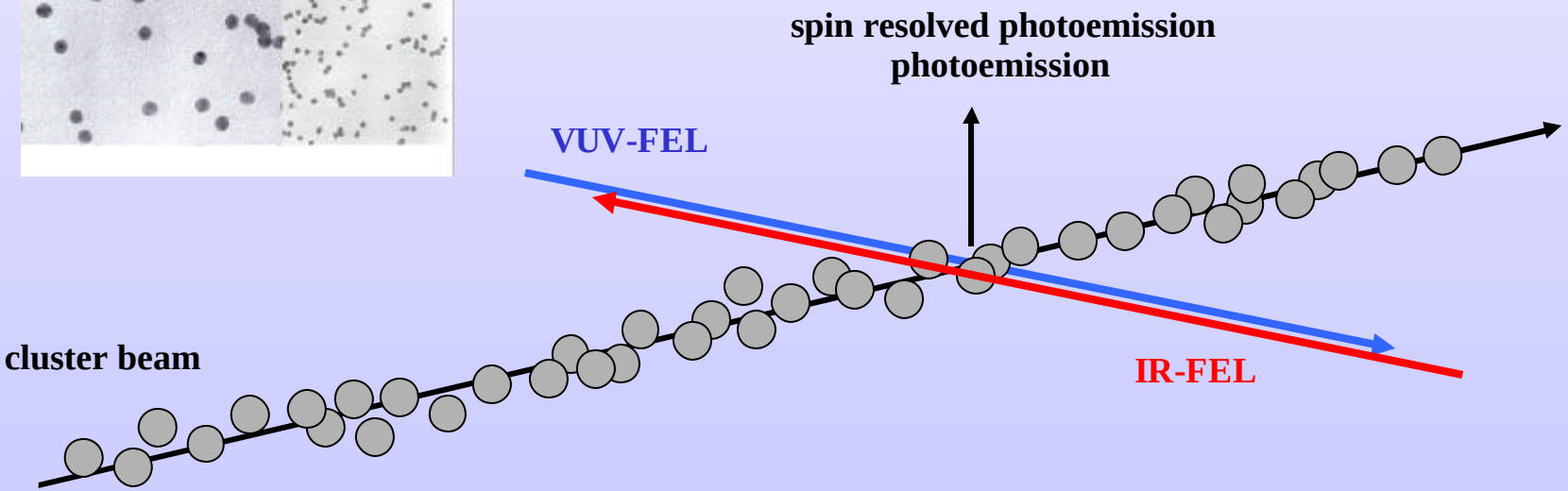
flux, brightness, timing

- nanoscience
- dynamics
- transients, excited states
- imaging
- non-linear/high field phenomena

Spintronics ...

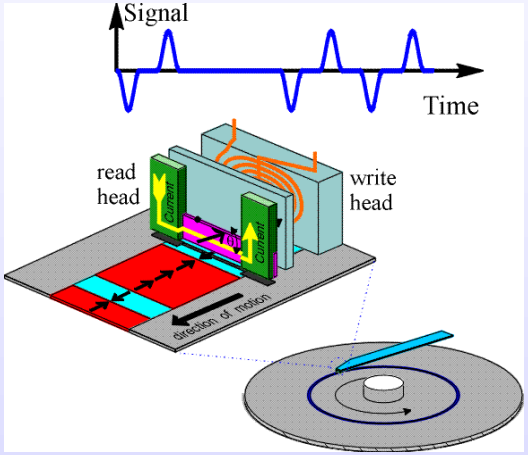


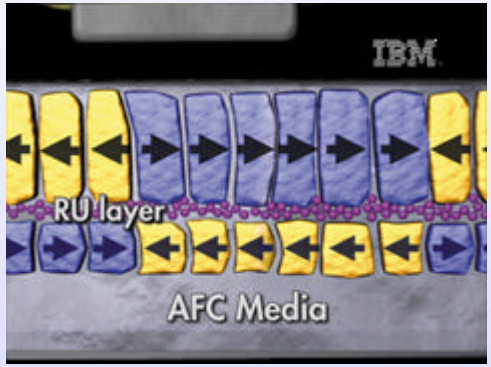
- the next generation of electronics devices
- study of individual nanoclusters of only a few atoms
- modifications resulting from deposition
- spin dependent transport, excitons



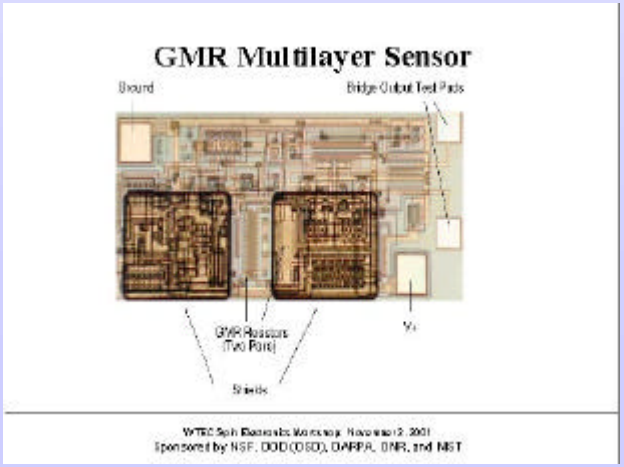
SHGMO, SPPES, MXCD, PEEM, pump-probe

Devices that utilise electron spin ...



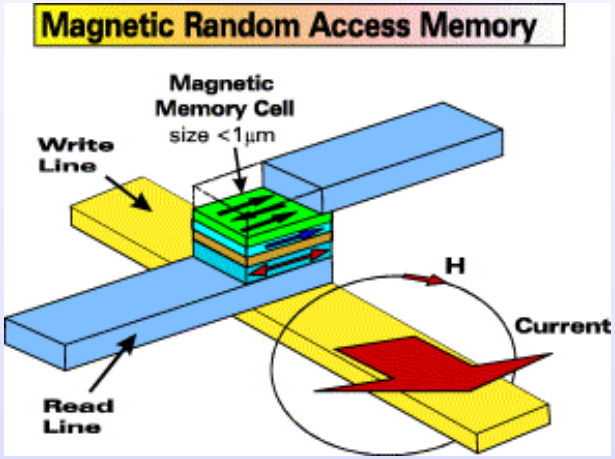


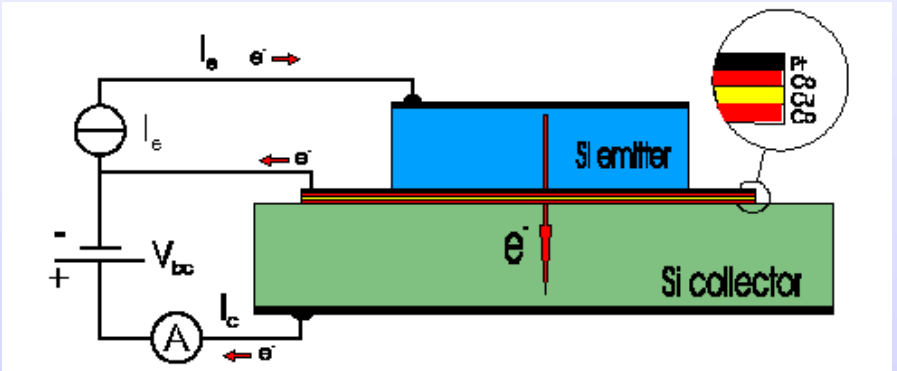
IBM Travelstar disc drive
uses spintronic read head sensors.
Areal bit densities up to 25.7 Gb per square inch achieved

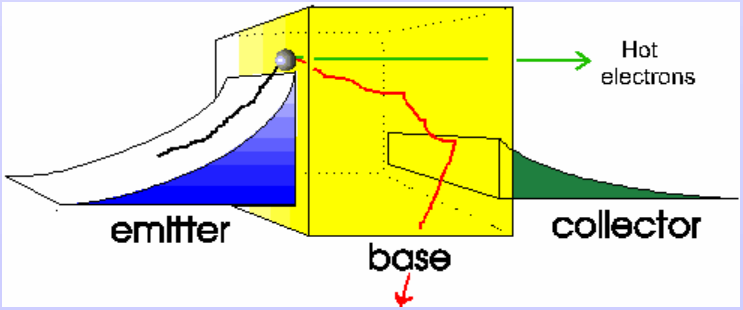


IBM web pages, James Daughton WTEC Workshop on Spin-Electronics

Future devices ...



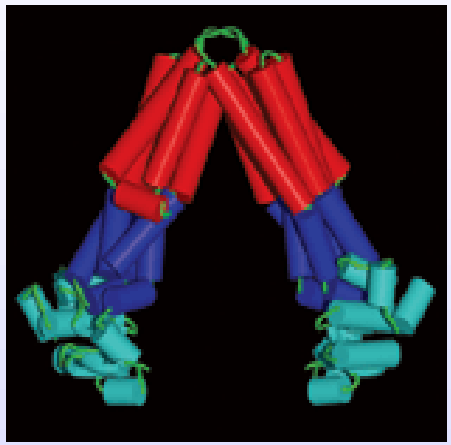




Monsma et al., PRL 74 (1995) 5260, Science 281 (1998) 407

Structure to function ...

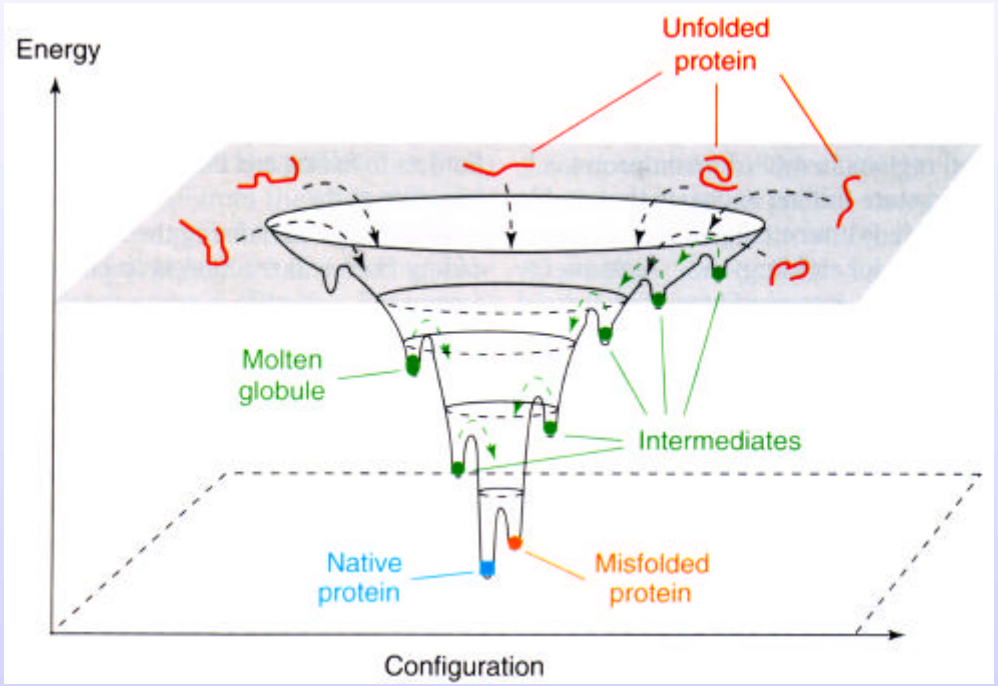
- crystal structures - static
- need to understand dynamics
- protein folding just one specific aspect
- complex coupling problem - far IR
  (collective modes) to electronic levels
  in UV - coupling critical to protein action
- variety of timescales - sub picosecond to minutes
- multi-wavelength pump-probe, time resolved CD, TR^3, IR, ROA



Science

CONNECT STRUCTURE TO DYNAMICAL BEHAVIOUR AND FUNCTION

Dynamics …



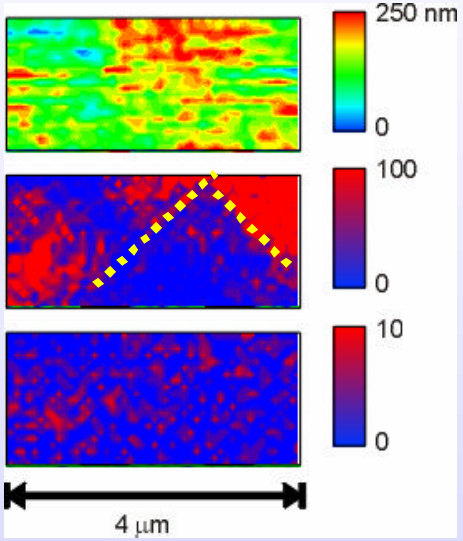
- IR-FEL, VUV-FEL, spontaneous radiation and TT laser/4GLS

- Real time protein folding; understanding how biomolecular structure relates to function; human diseases and novel therapies - advanced molecular dynamics simulations HPCx

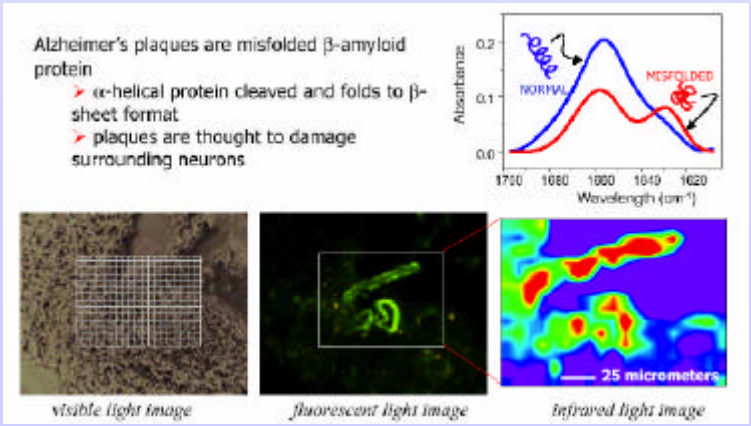
Imaging

Terahertz

Second Harmonic Generated Magneto Optics



IR



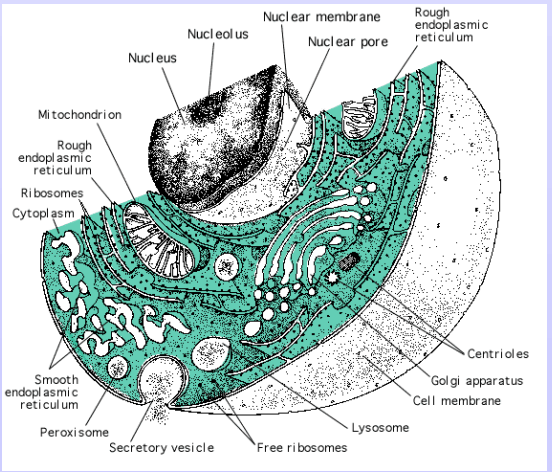
Dynamic soft-XPEEM clusters, spintronics

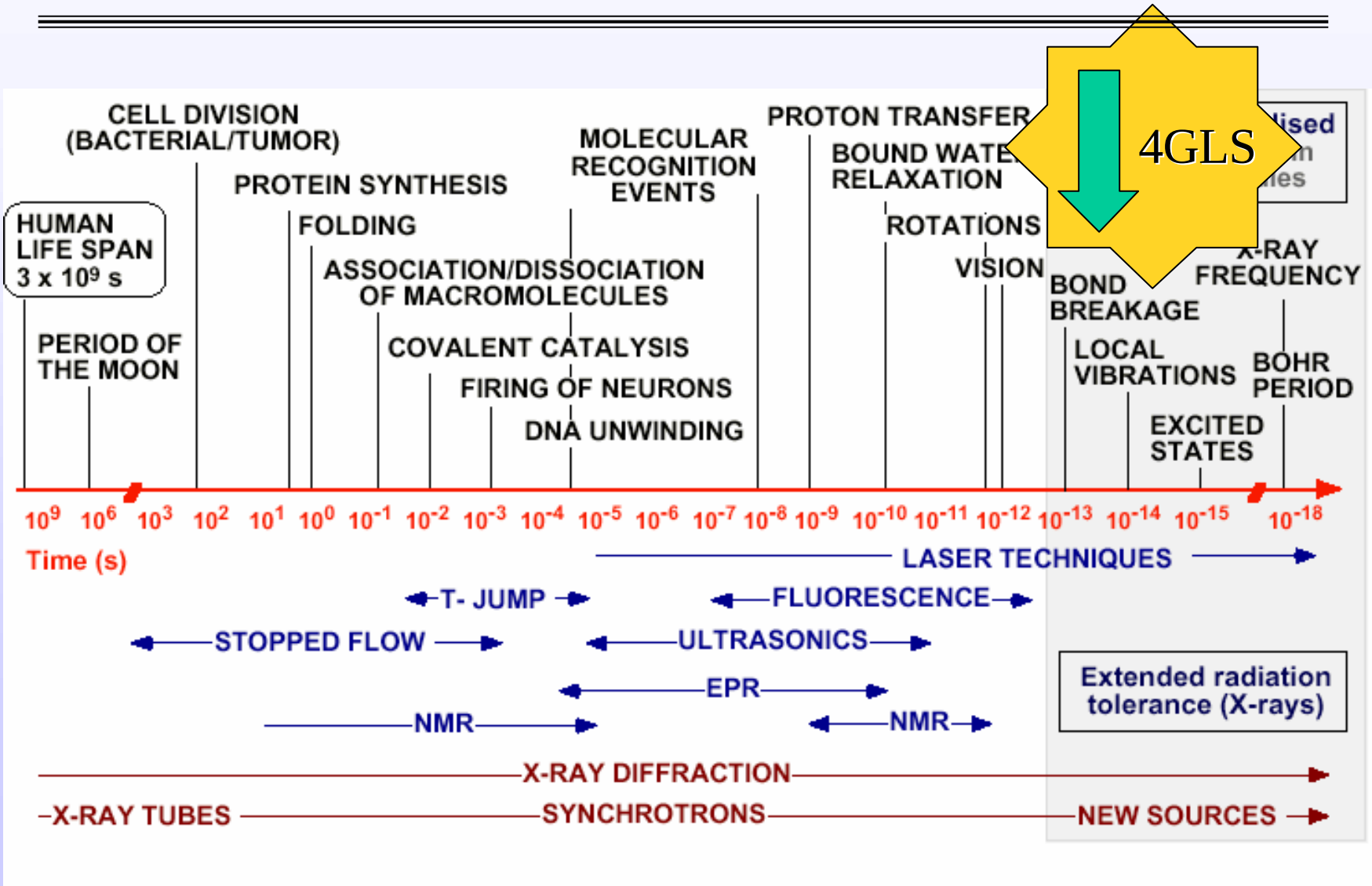
Imaging: spectroscopy and dynamics ...

- intercellular signalling, receptor systems on membrane rafts
- functional imaging in live cells, effects of pollutants, *in vivo* study of radiation damage
- material-biological matrix interface, surface nanostructuring

e.g. near field IR, UV RR spectroscopy, scanning near field SFS - localised imaging of sub cellular structures with resolutions approaching 30 nm

IR AND VUV FELs - SPATIAL AND DYNAMICAL INFO

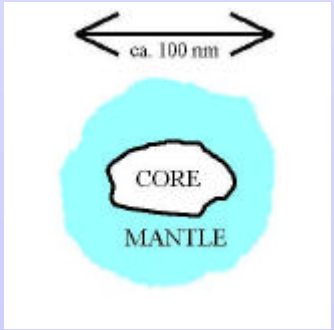




TESLA technical design report, March 2001

Pushing the limits …
astrophysics/astrochemistry

Molecular interactions on ultracold surfaces



- key fundamental measurements on multiply charged species - remove reliance on computed parameters
- chemistry of the interstellar medium - ion-surface and gas phase interactions, formation of complex ions and molecules
- enabling us to understand the origins of the universe

PES, TOF-MS, RAIRS, circularly polarised light from VUV-FEL

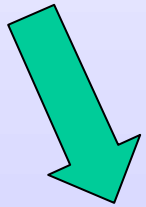
Non-linear phenomena

Examples

- multiphoton excitation dynamics of atoms, molecules and ions
- second harmonic magneto optics at shorter wavelengths
- spectroscopy of excited solids

Light-matter interaction in the high intensity, high frequency regime is little explored. Better understanding of coherent control mechanisms.

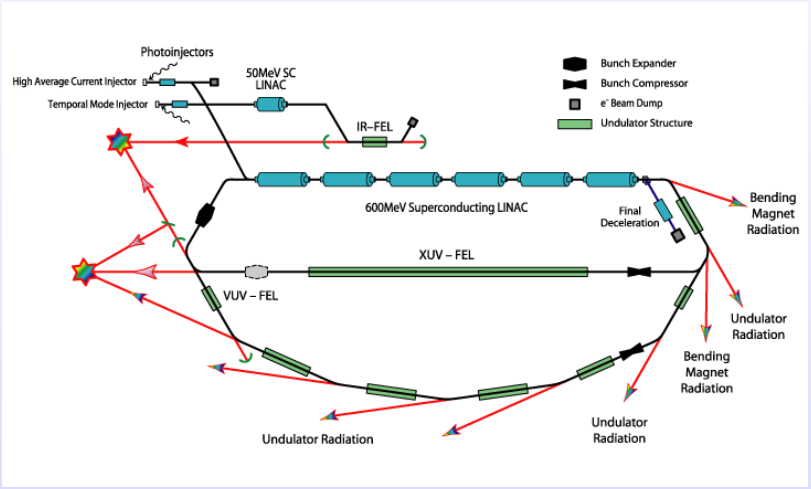
- resonanant behaviour > tuneability
- strong community of theoretical groups

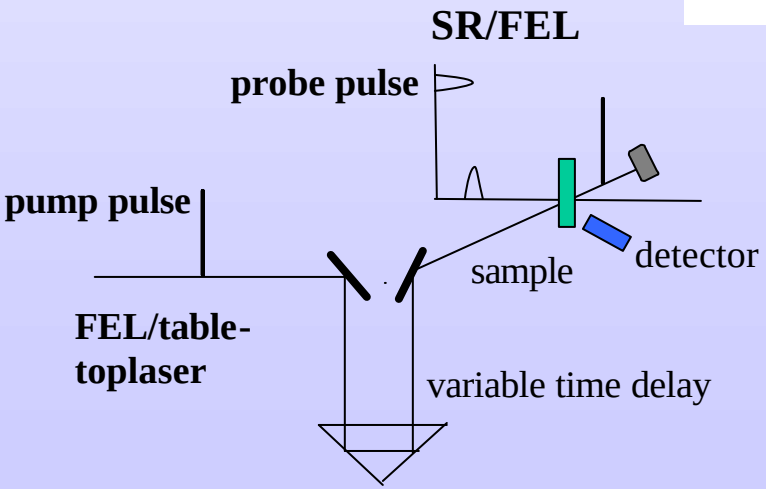


STRONG FIELD PHYSICS

uncharted territory

Unique experimental flexibility





- covers IR-XUV
- tailor pulses - selectable characteristics
- pump-probe options
- combine SR and lasers

Current position

Science Case

- 17th December 2001- *Science Case (220 authors) submitted*
- January/February - *Peer reviewed by EPSRC on behalf of OST*
- April 2002 - *RCUK recommend that 4GLS goes forward to Gateway 1. Project asked to undergo Gateway 1 by Nov/Oct*

Business Case

- 15th October 2002 - *Business Case prepared*

OGC Gateway 1 Review

- 4 days October 29th to November 1st - *Recommendations to improve the probability of success of the project*

Business Case

- **Major stakeholders identified**
  UK Scientific Community, DTI(OST), NWDA,CCLRC & other Research Councils
- **Major risks identified and assessed**
- **Options appraised: 4GLS is the option of choice**
  Other ways of meeting the science need not cost-effective

The facility should be:

- **located at Daresbury** - *for rapid and efficient implementation*
- **managed by CCLRC** - *consistent with post-QQR2 policy for large-scale facilities*

Influence release of R&D and Design Study funds ...

The bottom line ...

- **£5M to design**
- **£113M to build and commission (including VAT)**
- **£9.1M *per annum* to run (split approximately equally between staff and non-staff costs)**

NWDA

northwest development agency

The next steps ...

- **R&D**
- **build international and national collaborations**
  establish new links where needed
- **identify and pursue funding streams**
- **develop science case**
- **design study**

http://www.4gls.ac.uk