Micro Beams in Physical and Chemical Analytical Applications

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Terminology/instrumentation

- Particle accelerators and Micro Beams
- Micro Beams and Microprobes:

  A microprobe is an instrument that applies a stable and well-focused (micro!) beam of charged particles (electrons or ions) to a sample
  - Focused Ion Beams (FIB) instruments
  - electron microprobes (like scanning electron microscope)
  - ion microprobe: two different clases of instruments
    - employing SIMS (Secondary Ion Mass Spectrometry)
    - nuclear microprobe (nuclear microscope)
- Another Micro Beams associated with accelerators:
  - accelerator based (mainly synchrotron) x-ray Micro Beams

Focused Ion Beams (FIB)

- usually gallium ions accelerated to 5-50 keV focused onto the sample by electrostatic lenses
  - site-specific analysis, deposition and ablation of materials
  - micro-machining tool (sputtering)
  - ion beam induced deposition of material
  - modifying existing semiconductor device
  - sample preparation for TEM

- variation: helium ion microscope
  - Helium ions with 25-30 keV energy for surface imaging and material surface composition analysis by Rutherford Backscatering (RBS).
  - Spatial resolution less than 0.9 nm
  - high quality images: comparable or better than SEM

Electron Microprobes

- Scanning Electron Microscope (SEM)
- Transmission Electron Microscope (TEM)
- High-Resolution TEM
- Reflection Electron Microscope (REM)
- Scanning Transmission Electron Microscope (STEM)

- probably the most videly used of those mentioned here
- imaging, elemental composition, etc...

Ion Microprobe – employing SIMS

- chemical analysis of small volumes of materials
- surface of the sample bombarded under vacuum with a finely focused beam of primary ions (Cs+, O+, O-, Ar+), secondary ions from the sample analysed by spectrometer
- point analysis: composition in a point, spot size 1 to 25 μm
- depth profiling: scanning of primary ions, surface layers slowly eroded
- Imaging: elements/isotopes distribution, spatial resolution about 1 micrometer
- Low energy and high-energy SIMS
  - low-energy: energies in the keV range
  - high-energy SIMS involves use of ion beam accelerators (two applications/configurations)
    - SIMS injector, secondary ions anaysed by acceleration to the MeV energies (sort of AMS: SIMS-AMS)
    - High energy primary beam, analysis of molecular ions from the sample

Nuclear Microprobes

- Ion beams with typical energies of several MeV to focused to sub-micrometer dimensions and scanned
- Ion Beam Analysis (IBA)
- Ion Beam Modification of Materials
  - typicaly installed with electrostatic accelerators, MeV ions
  - much larger installations than the previous ones
  - quite limited number

Table 1: Nuclear microprobe facilities around the world.

Country	Number of installations	Country	Number of installations
In Europe:		**North and South America:**	
		Argentina	1
France	3	Canada	1
Hungary	2	USA	8
Germany	5		
Italy	2	**Asia and Australia:**	
Netherlands	1	Australia	3
Poland	1	China	2
Portugal	1	India	2
Spain	1	Iran	1
Slovenia	1	Japan	1
Sweden	1	New Zealand	1
UK	1	Singapore	1
Total in EU:	**19**	Saudi Arabia	1
Croatia	1	**Africa**	
Ukraine	1	South Africa	2
		Total:	**45**

Accelerator based (mainly synchrotron) light (including x-rays) sources

- **some of them** provide focused light (inluding x-rays) micro beams
- lightsources.org lists 69 synchrotron light sources based on storage rings and free-electron lasers (operational, planned, in construction, ...)

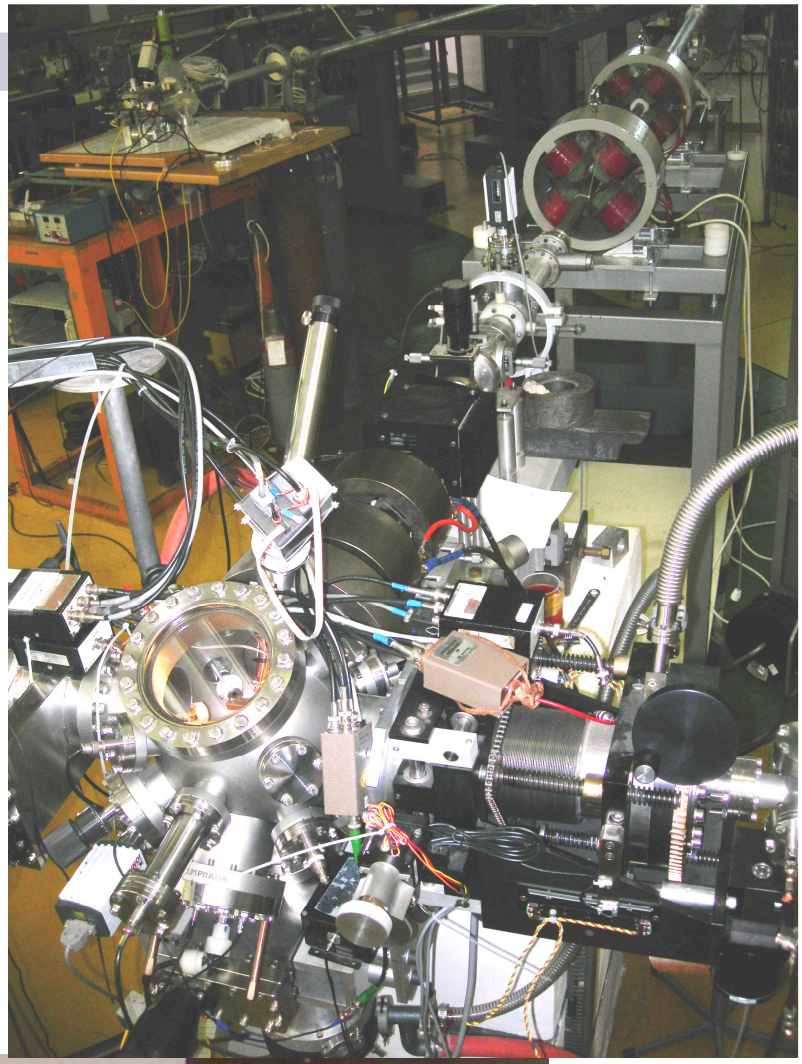
Table 1: Light source facilities around the world (storage rings + free electron lasers).

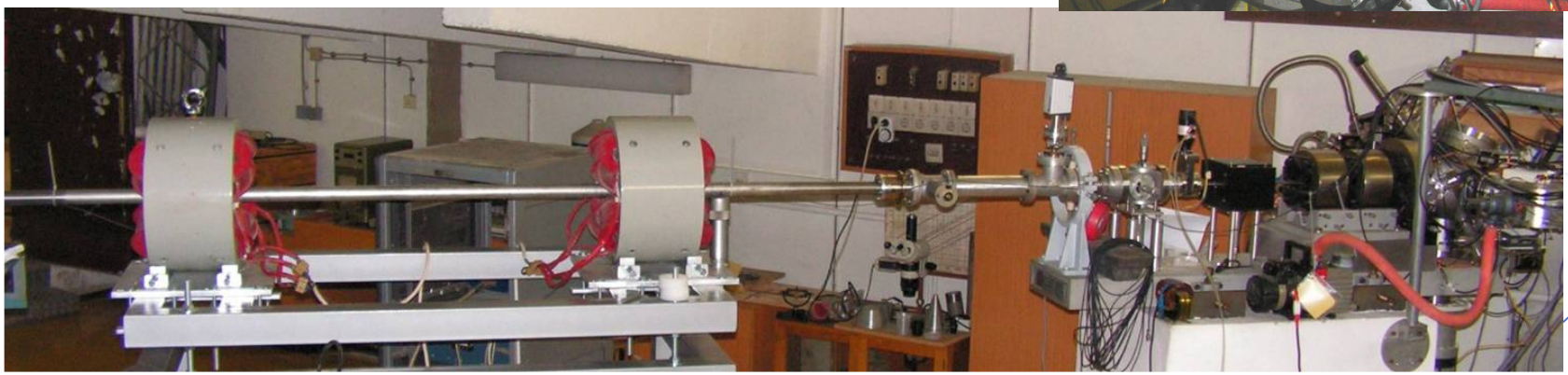
Country	Number of installations	Country	Number of installations
In Europe:		**North and South America:**	
Czech R.	1	Brazil	1
Denmark	1	Canada	1
France	3	USA	16
Germany	7		
Italy	2	**Asia and Australia:**	
Netherlands	1	Armenia	1
Poland	1	Australia	1
Spain	1	China	4
Sweden	1	India	1
UK	1	Japan	14
		Jordan	1
Total in EU:	**19**	Singapore	1
		South Korea	1
Russian Federation	4	Thailand	1
Switzerland	1		
Ukraine	2	**Total:**	**69**

RBI nuclear microprobe

- PIXE, RBS, ERDA,
- IBIC, STIM
- Coincidence scattering
- Ion hit detection (SE & IL)

- Focusing system – quintuplet
  - ME/q2 < 25
  - Equal demagnification
  - 0.5 μm – smallest beam size





Thank you