Hahn-Meitner-Institut

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Deutsch

ISL - Berlin

- a Center for Ion-Beam-Techniques -

Direction: Dr. Andrea Denker

From 1994 until 2006 ISL offered ion beams with energies ranging from some tens of eV to some hundred MeV dedicated to the application of ion beam techniques in solid state physics, material science and biological science. Hence, ISL provided a third tool for the investigation of condensed matter and surfaces along with the neutrons of BER II and the photons of BESSY II. Researchers at ISL used ion beam techniques in various fields: eye tumor therapy, analysis, applications, and research. About 70% of the beamtime was utilised by external users (see user information) .

Having the choice to reinforce either the research at the reactor or to strengthen the research at ISL, the senate of the Helmholtz-Society (HGF) recommended a closure of ISL at the end of 2007. Thereupon, the board of governors decided to close the ISL at the end of 2006.

These pages reflect the status of ISL at the end of 2006 and there will be no further update.

Ion beam analysis at ISL

The accelerators at ISL are used for basic research, for the modification of materials and for the analysis of matter. The objects under examination vary from complicated layer structures of semiconductor devices to those of art historical nature. The following methods are available also for external customers:

ERDA	(Elastic Recoil Detection Analysis)
PIXE	(Proton induced X-ray emission)
RBS	(Rutherford Backscattering with helium or heavy ions)
15N	(Hydrogen depth profiles by means of resonant nuclear reaction)

Here, you will find a summerizing overview of sensitivities, resolutions, etc. for the different methods.

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ERDA

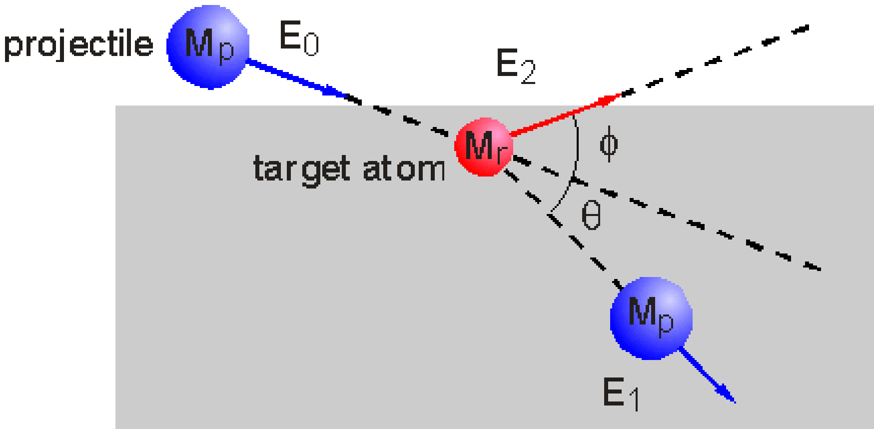
(Elastic Recoil Detection Analysis with high energetic heavy ions)

For the ERDA-method the samples are irradiated with high energetic heavy ions under grazing conditions. The energy as well as the number of the outscattered atoms (recoils) of the sample components are measured at a fixed angle relative to the beam direction. At ISL the element - respectively mass identification is done by means of the time-of-flight method (TOF), i.e., the coincident measurement of energy and flight time for each recoil. Owing to the element specific energy loss in material it is possible to calculate from the measured energy spectra the depth dependent concentration distributions for all components of a sample.

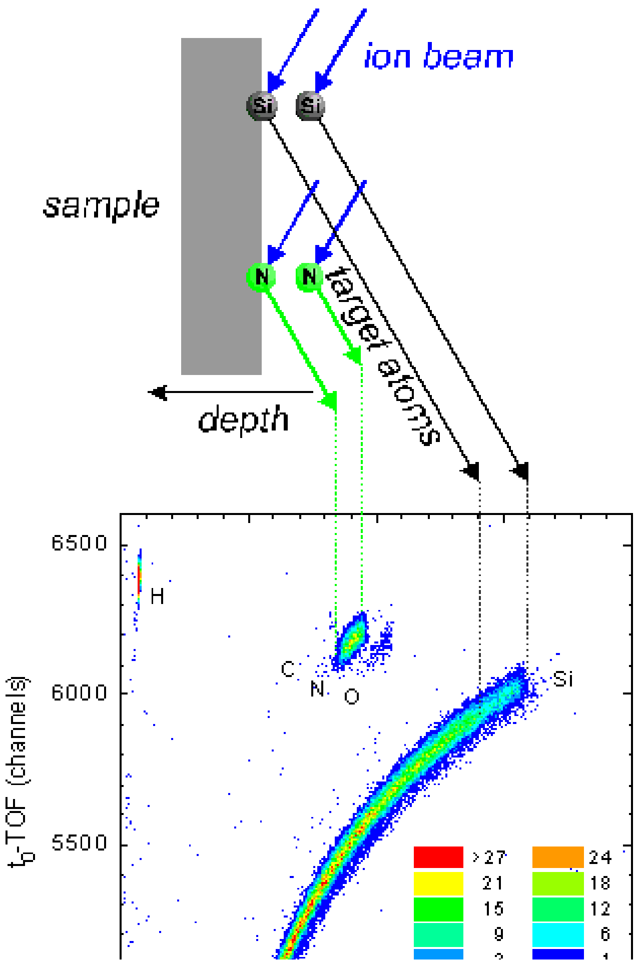
Principle
Setup
Team
Publications
Sample sheet

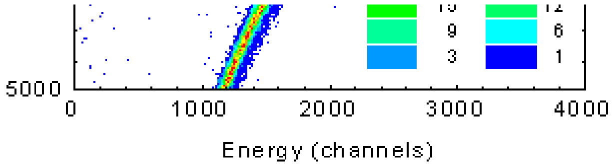
ERDA-measuring principle

- irradiation of the sample with high energetic heavy ions at grazing incidence



- coincident measurement of energy and time-of-flight with fixed flight path for the outscattered atoms of the sample
- according to *E=M/2 v*^{2} it is possible to identify and separate the various masses in the two-dimensional scatterplot time vs. energy





scatterplot (time vs. energy) of atoms from a SiN_x:H layer on Si scattered to 60° relative to the direction of the irradiating beam of 230 MeV ^{129}Xe-ions

- the concentration of each element is calculated from the measured number N_r' of the corresponding forward scattered atoms from the sample

$$N_r = \frac{N_r'}{\sigma_r \, \Delta\Omega \, N_0}$$

- the solid angle $\Delta\Omega$ of the setup is known
- N_0 the number of the incident projectile ions is measured without any disturbance of the beam using the residual-gas-ionization
- the differential Rutherford cross section for the forward scattering of the sample atoms with mass M_r and nuclear charge Z_r can be calculated exactly

$$\frac{d\sigma_r}{d\Omega} = \left(\frac{Z_p Z_r e^2}{2E_0}\right)^2 \left(\frac{M_p + M_r}{M_r}\right)^2 \frac{1}{\cos^3\phi}$$

- no free parameter is left, i.e., ERDA is a standard free, absolute method
- the thickness of a layer and the concentration profiles are calculated from the measured energy difference of the forward scattered sample atoms relative to the maximum possible energy of an atom scattered to the detection angle, which is given by the kinematical factor

$$E_2 = k_r E_0$$

$$k_r = \frac{4 M_p M_r \cos^2\phi}{(M_p + M_r)^2}$$

- the detection sensitivity is almost the same for all elements
- only for hydrogen the sensitivity is enhanced by a factor of four
- when using heavy projectile ions no restriction of the detectable mass range exists
- possible uncertainties of the used stopping cross sections result in uncertainties of the calculated depth distributions

ERDA contact ERDA top

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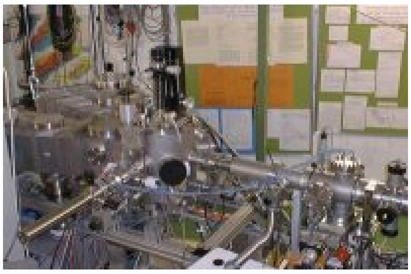
1994-2006

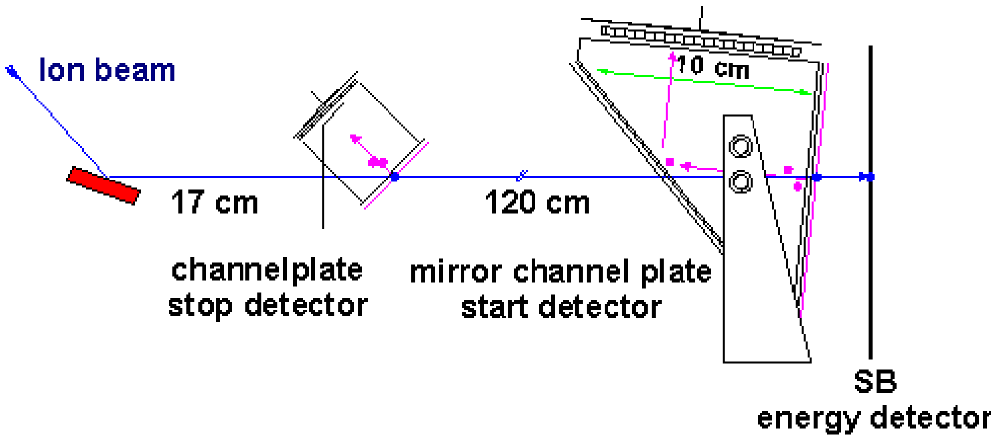
ERDA-setup:

Scattering chamber:



enlarged picture (159 kB)

Flight path:



Parameters:

Sample dimensions:	1 cm x 1 cm
Sample lock:	6 samples per ladder
Scattering angle:	$\Phi = 15° - 45°$
SB-detector:	72 mm x 60 mm, 24 stripes each 3 mm wide
Detector opening:	$\Delta\Phi = \pm 1.45°$ (24 x 0.12°)
Solid angle:	$\Delta\Omega = 2.1$ msr
Flight path:	d = 120 cm
Time resolution:	$\Delta t = 150$ ps
Typical ion beam:	230 MeV $^{129}Xe^{17+}$, ca. 0.3 TnA
Measurement time:	10 - 100 min

Sensitivity:	some ppm for H and heavy elements, maximum 10 ppm for the others, depending on the sample structure
Depth resolution:	about 10 nm close to the surface, decreasing with increasing depth
Maximum depth:	about 2 µm, depending on the material

ERDA contact

ERDA top

Publications RBS/ERDA:

2005

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ERDA contact ERDA top

PIXE

(Proton Induced X-Ray Emission)

The object, that is to be analyzed, is irradiated by high energy protons. They excite the atoms, to emit characteristic X-rays, which identify the chemical elements in the probe. Very low proton currents are needed, and the studied objects are in normal atmosphere. Therefore highly sensitive and large objects, as objets d'arts, can be studied without any damage.

Fig: Analysis of the gilding of a 3600 year old egyptian coffin.

Principle
Setup
Contact
Publications

I S L - BERLIN
1994-2006

PIXE-measuring principle

Irradiation of any material with a proton beam induces the emission of characteristic X-rays, that identify the elements in the material, independent of their chemical bonding. Only X-rays above about 2 keV, i. e. from elements heavier than phosphorous, can be detected with the object in air due to the absorption of the X-rays in the air and the vacuum window of the detector; often the pieces to be analyzed would be damaged, if brought into vacuum. PIXE is performed at many places with protons of about 3 MeV. Here 68 MeV protons are used. With low energy protons the analysis is limited to a depth of around 0.25mm by the range of the protons. The range of 68 Mev protons is roughly a few centimeters, offering the fairly unique possibility of a nondestructive analysis to this depth. 68 MeV protons induce also for the heaviest elements the emission of K X-rays with good cross sections. These high energy X-rays are little absorbed and can therefore also be detected from deep inside of any test piece. The spectrum of K X-rays is also much less complicated than that of L X-rays, which have to be used with the usual low energy protons. The absorption of the X-rays on their way out from deep inside of the studied object, that depends on the composition and any layer structure of the probe, makes a fully quantitative analysis of the elements difficult. Some information on the depth, in which an element is present, can be gained from the measured intensity ratios of the various K and L lines of this element. Their absorption in the probe differs markedly because of their different energy and depends therefore on the depth.

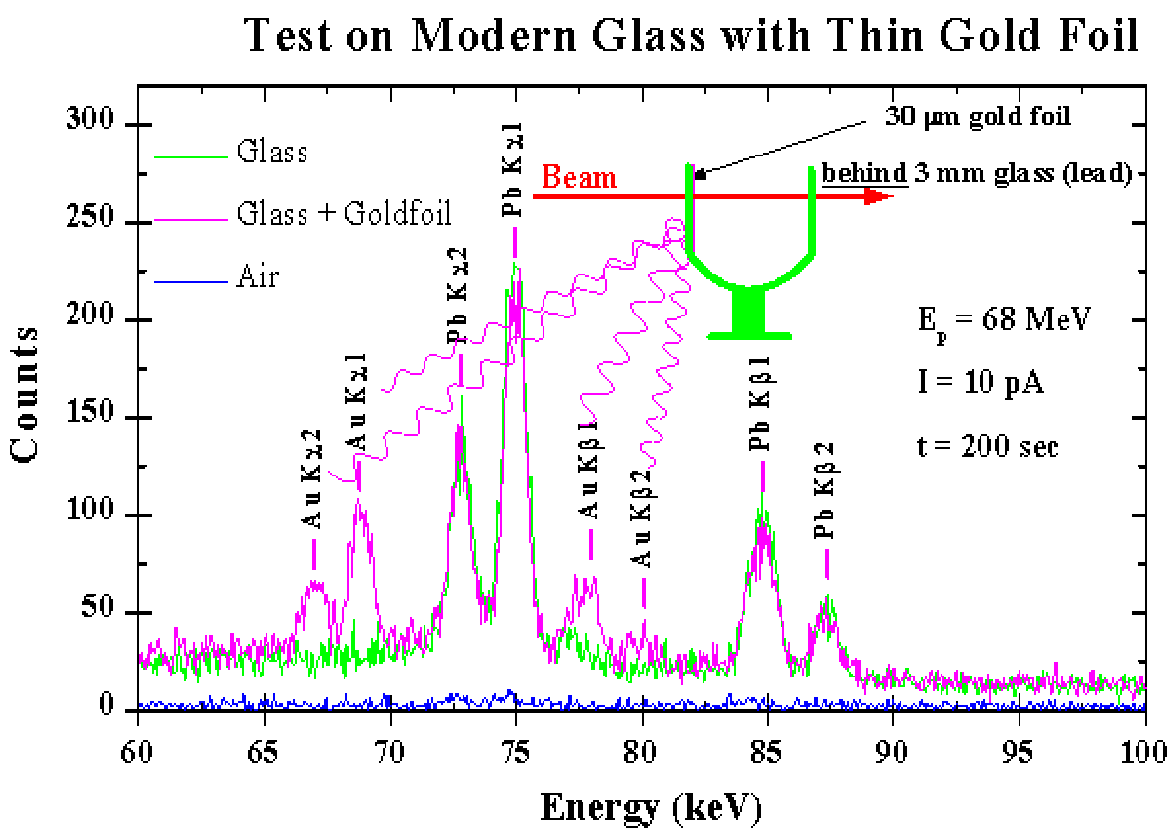


Fig: Non destructive detection of a thin gold foil behind 3mm of lead glass.

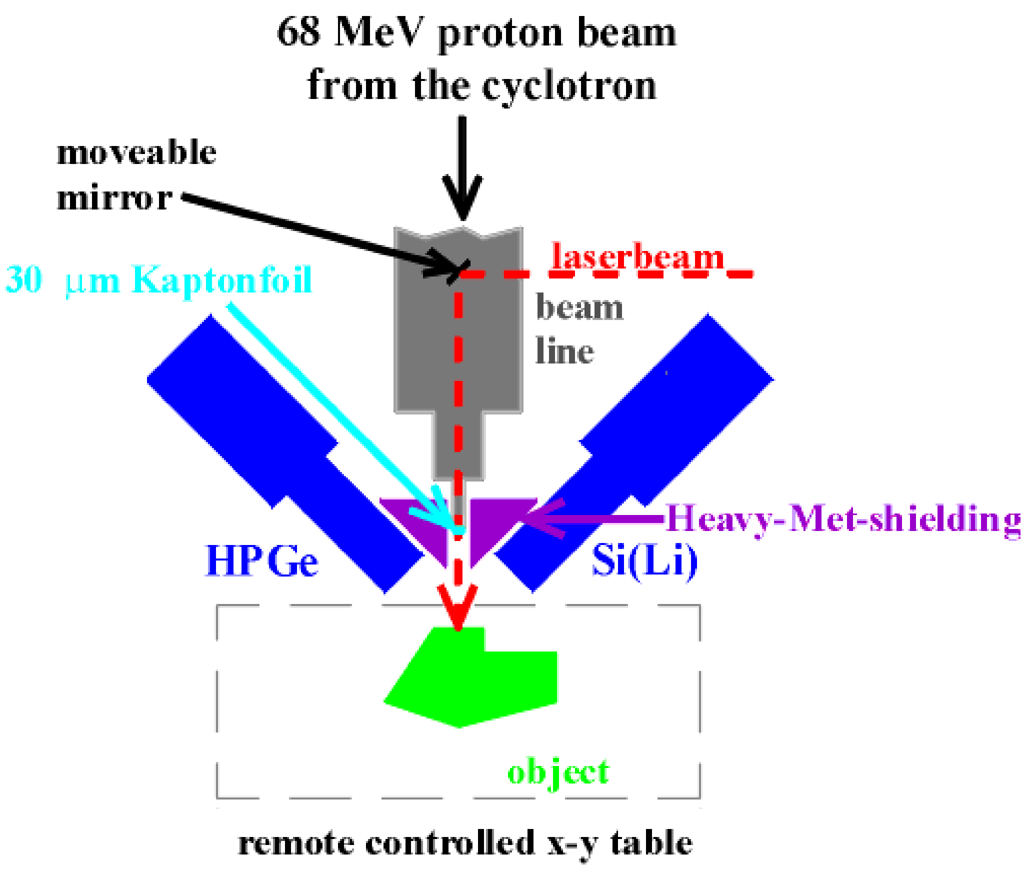
[PIXE contact]() [PIXE top]()

I S L - BERLIN 1994-2006

PIXE-setup:

The simple measuring set up is placed at target location TW. The proton beam exits through a thin Kapton foil into the atmosphere. The item to be tested is placed about 10 cm behind the foil on a remote controlled x-y-table. Also bulky and heavy (50kg) pieces can be positioned to 0.1 mm. The measured spot can be marked and documented by taking and storing a digital image with a TV-camera. The beam is first focussed on a luminescent screen with an intensity of 1 nA to a diameter of 0.1 mm or more. Then the beam current is reduced to < 1 pA, before the object and the Ge- and Si(Li)-detector for the X-rays are put into place. Typically one measurement takes 3 min.

Setup:



Parameter:

size of object	1 mm to 1m
distance beam exit to object	10 cm
distance detector to object	5 cm
detector HPGe	180 eV @ 5.9 keV
detector Si(Li)	155 ev @ 5.9 keV

Beam	68 MeV Protons, below 10 pA
measuring time	200 sec bis 0.5 h
Sensitivity	1 ppm for elements with Z around 50 in a light matrix, decreasing 0.1% in unfavourable cases
depth resolution	ca. 10 µm
possible depth of analysis	depends on element and matrix, up to some cm

PIXE contact PIXE top

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Publications PIXE:

2006

COST Action G8: non-destructive testing and analysis of museum objects
A. Denker, A. Adriaens, M. Dowsett, A. Giumlia-Mair (Editors)
ISBN 978-3-8167-7178-4 Fraunhofer IRB Verlag

Materials Analysis Using Fast Ions
A. Denker, W. Bohne, J. Rauschenberg, J. Röhrich, E. Strub
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PIXE Kontakt PIXE Anfang

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RBS

(Rutherford Backscattering with helium or heavy ions)

For the RBS method a sample is irradiated with light energetic ions, typically hydrogen, helium or neon of a few MeV. At a backward angle, close to 180° relative to the beam direction, the number and the energy of projectile ions backscattered from the target are measured. Since these values are dependent on the mass respectively on the nuclear charge of the scattering atoms and because the projectiles sustain an energy loss in the material it is possible to determine the elemental composition as a function of depth.

Principle
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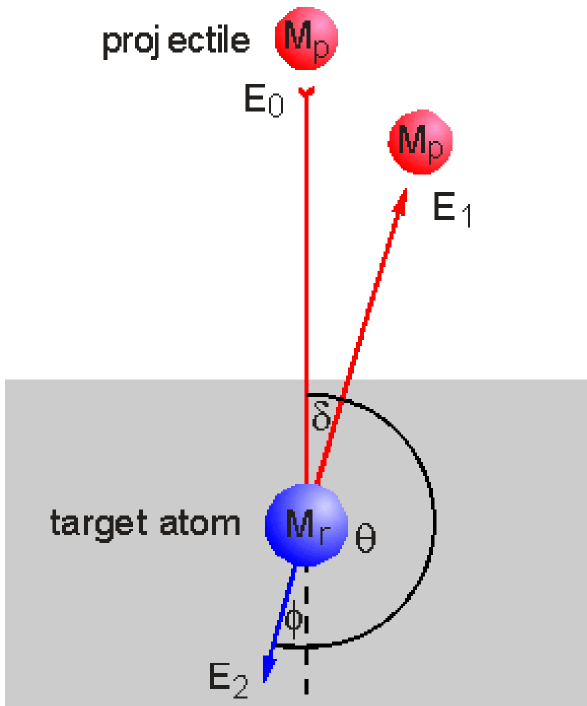
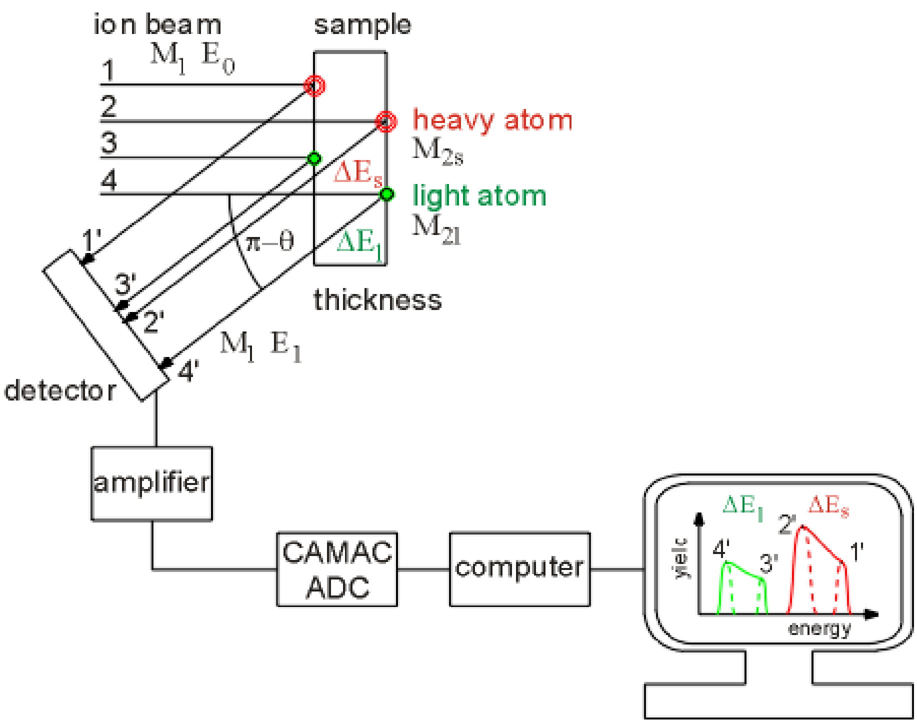
RBS-measuring principle

- irradiation of the sample with light ions and detection of the elastically backscattered projectiles at large angles



- the mass identification of the target atoms results from the energy of the backscattered projectile, typically measured by means of a surface-barrier detector



- using heavier ions e.g. ^{14}N allows a better mass separation compared to so called standard RBS using H- or He-ions as projectiles
- the thickness of the layer respectively the concentration profile is determined from the energy difference of the backscattered projectile referring to the corresponding maximum energy for the scattering at a surface atom, given by the kinematical factor

$$E_1 = k_p E_0$$

$$k_p = \left(\frac{M_p / M_r \cos\theta + \sqrt{1 - (M_p / M_r)^2 \sin^2\theta}}{1 + M_p / M_r} \right)^2$$

- in the case of thicker samples the mass identification may be complicated due to the superposition of the spectra originating from the various sample components
- the number N_p of the measured backscatterd projectile ions gives the concentration of the corresponding element

$$N_r = \frac{N_p}{\sigma_p \, \Delta\Omega \, N_0}$$

- the solid angle $\Delta\Omega$ for the setup is known
- N_0 the number of the incident projectile ions is measured without any disturbance of the beam using residual-gas-ionization
- for the energies used, the differential Rutherford cross section for the scattering of a projectile with the nuclear charge Z_p from a target atom with the elemental number Z_r can be calculated exactly

$$\frac{d\sigma_p}{d\Omega} = \left(\frac{Z_p Z_r e^2}{2E_0} \right)^2 \frac{1}{\sin^4\theta} \frac{\left(\cos\theta + \sqrt{1 - (M_p / M_r \sin\theta)^2} \right)^2}{\sqrt{1 - (M_p / M_r \sin\theta)^2}}$$

- no free parameter is left, i.e., RBS is a standard free, absolute method
- since the scattering probability increases with Z_r^2 RBS is more sensitive for heavier components of the sample
- scattering to large angles from atoms with masses close to or even below the projectile mass is not possible, therefore, these light elements are not detectable
- possible errors in the used stopping cross section result in errors of the calculated depth distributions

RBS contact RBS top

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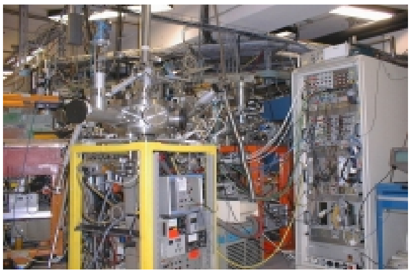
RBS-setup:

Scattering chamber for heavy-ion RBS:



enlarged picture (203 kB)

Parameters:

Sample dimensions:	1 cm x 1 cm
Sample lock:	7 samples per ladder
Scatter angle:	$\theta = 165°$
Distance between detector and sample:	d = 10 cm
Detector opening:	$\Delta\theta = \pm 1.2°$
Solid angle (4 detectors):	$\Delta\Omega = 22.2$ msr
Typical ion beam:	15 MeV $^{14}N^{4+}$, about 5 TnA
Measurement time:	10 - 100 min
Sensitivity:	ppm for heaviest elements in light samples down to 0.1% for light elements
Depth resolution:	about 10 nm close to the surface, decreasing with depth
Maximum depth:	about 2 µm, depending on the material

RBS contact RBS top

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RBS contact RBS top

Ion Irradiation at ISL

Owing to its broad range of accelerators, the ISL is able to provide light to heavy ions over a very wide energy spectrum. Mean ion range, energy dose, ion flux and irradiated area can be adapted to the specific requirements of the indidual experiment.

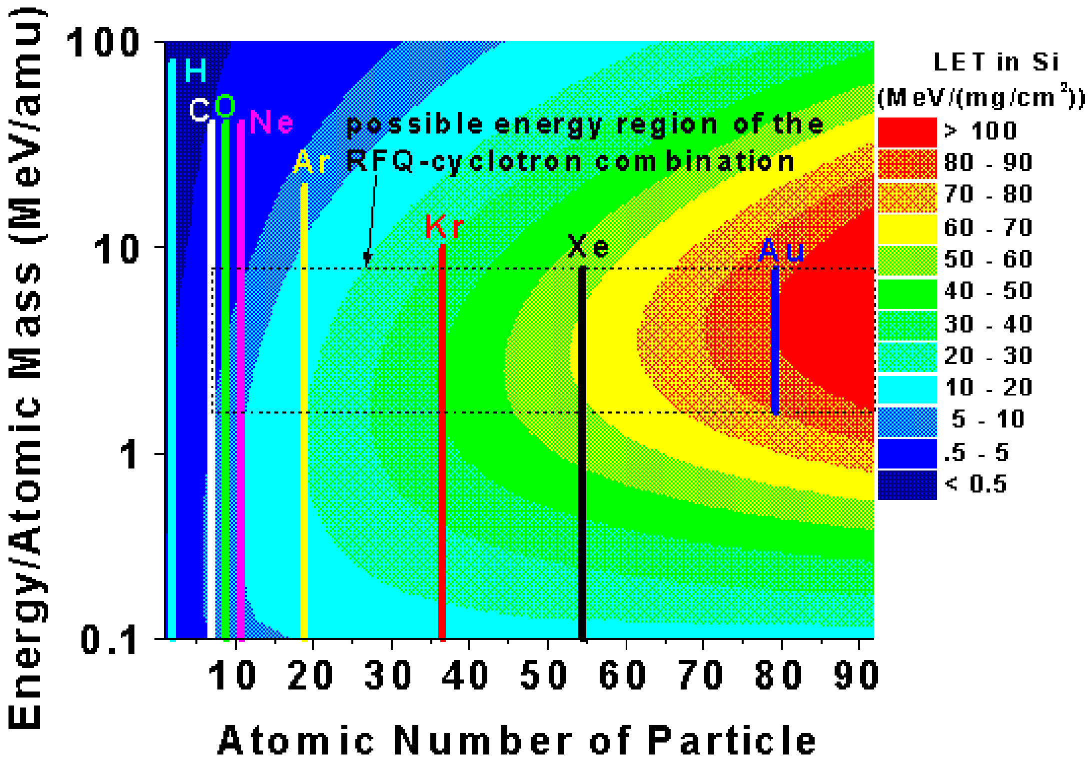

Abb. 1: Linear energy transfer (LET) of ions in silicon.

Contact: Dr. A. Denker

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Materials Modification
Radiation Hardness Tests
BIBER

Materials Modification at ISL

Fast, heavy ions deposit more energy locally in a shorter time than can the most powerful lasers currently available. The extremely high energy deposition along the flight path of an ion can destroy the chemical bonds, so that permanent material modifications are left in its track. The resulting materials modifications are already being technologically exploited:

- change of optical properties (e.g. laser diodes)
- ion lithography
- production of microfilters by etching the ion tracks

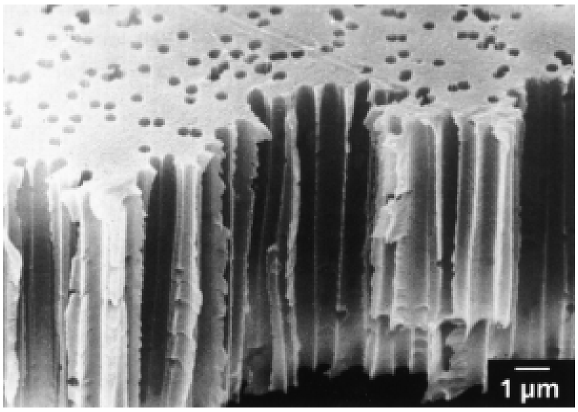

Fig. 1: Scanning Electron Microscope picture of an irradiated foil after the etching. The picture shows the entrance holes of the ions at the surface and the channels at the edge.

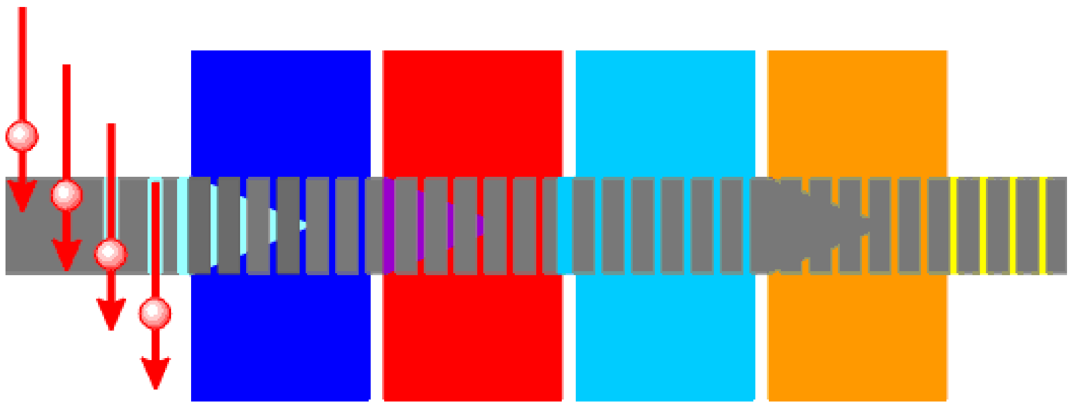

Fig. 2: Principle of the foil production.

Applications of microfilters:

- counters for blood particles (single track)
- particle filters, e.g. dust-free air-conditioning for clean rooms
- air filters, e.g. capsuled electro motors

Contact: Dr. A. Denker

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RadHard Tests at ISL

When a high-energy ion passes through electronic devices the ionisation in the track can destroy or switch the status of the device. Each measurable effect on an electronical device produced by an impinging ion is called Single Event Effect (SEE).

High-energetic ions are part of cosmic radiation, solar wind, and radiation belts of the earth. Especially the electronics in aircrafts and satellites is subject to this radiation. The radiation hardness of the devices can be tested by ion irradiations, which simulate the operation conditions. Thereby the devices receive the same dose as they would receive during their operation lifetime.

At ISL there are two experimental set-ups in ordinary air in the high-energy portion of the accelerator complex: At these target stations, the ion beam leaves the vaccum of the beam line through a thin foil. Hence, there are no restrictions in size or fragility of the object being irradiated. Thus electronic devices can be irradiated while in normal operation and electrical or optical measurements can be carried out.

Ion irradiations in vacuum can be performed at different target areas. A large chamber allowing irradations of all kinds in vacuum is available at the dual-beam line of ISL.

contact
articles

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Publications to RadHard Tests

(Articles of guest groups are marked in green)

2000

Charge Carrier Avalanche Multiplication in High-Voltage Diodes Triggered by Ionizing Radiation
G. Soelkner, P. Voss, W. Kaindl, G. Wachutka, K.H. Maier, H.-W. Becker
IEEE Transactions on Nuclear Science, Vol. 47, No. 6 (2000), 2365-2372

Calibration of Si-Detectors for Dosimetry in Space
C. Gericke, J. Kopp, R. Beaujean, S. Küchler
ISL Annual Report 1999 (2000) 101

1999

Strahlungstest der ABRIXAS-Sternkamera
D. Meinert, K. Fritze, M. Bischof, E. Popow, B. Luebke-Ossenbeck, K.H. Maier
ISL Annual Report 1998 (1999) 74

1998

Single Event Burnout of High-Power Diodes
K.H. Maier, A. Denker, P. Voss, H.-W. Becker
NIM B 146 (1998) 596-600

SEE contact SEE top

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Materials Modification
Radiation Hardness Tests
BIBER

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BIBER

(Berlin IonBeamExposure andResearch Facility)

BIBER – the Berlin Ion Beam Exposure and Research facility – is a new and universal irradiation station at the dual beam target place of the ion beam laboratory ISL of the Hahn-Meitner-Institute. Possible experiments are ranging from radiation hardness tests of electronic devices to materials modifications. On the one hand lowest possible ion beam currents and fluences are mandatory whereas on the other hand ion fluxes and doses can reach up to the highest possible limit. Beams of fast ions can be prepared by different combinations of accelerators. They can be applied to samples inside the BIBER facility simultaneously or successively with beams of slower ions.

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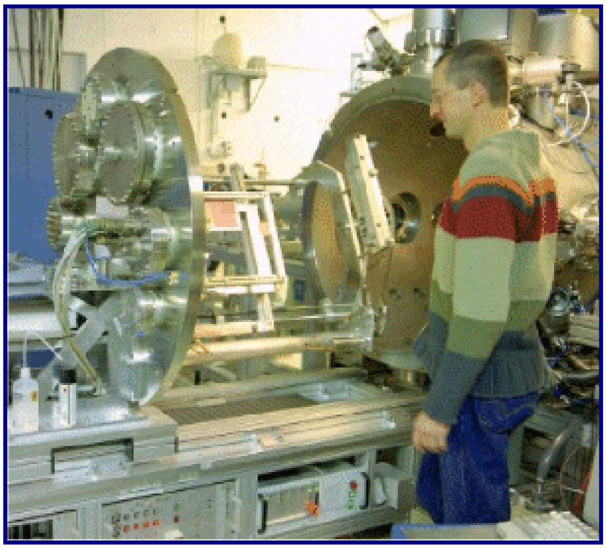

foto set-up, 0.4 MB

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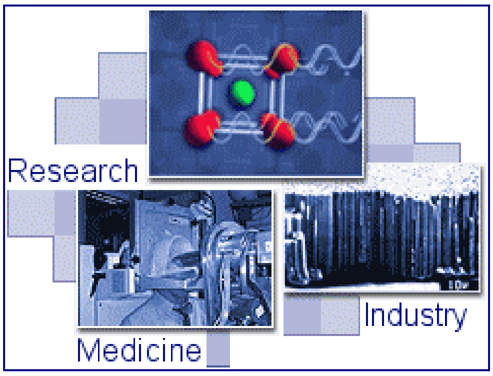
Research with Ion Beams



Apart from providing the user service for applications of ion beams in medicine, industry, and analysis the department: Struktur & Dynamik (SF 4) operates the ISL-Berlin for experiments in fundamental and applied research.

However, not only ion beams, but also other methods and probes are used in this department, especially in co-operation with the other large scale facilities in Berlin: BESSY and BER II.

You will find more detailed information on the homepage of the department: Struktur & Dynamik.

In addition, ISL publishes a printed newsletter with actual information and research results (mainly in German). You will find these under: ISL-Info.

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ISL - Berlin

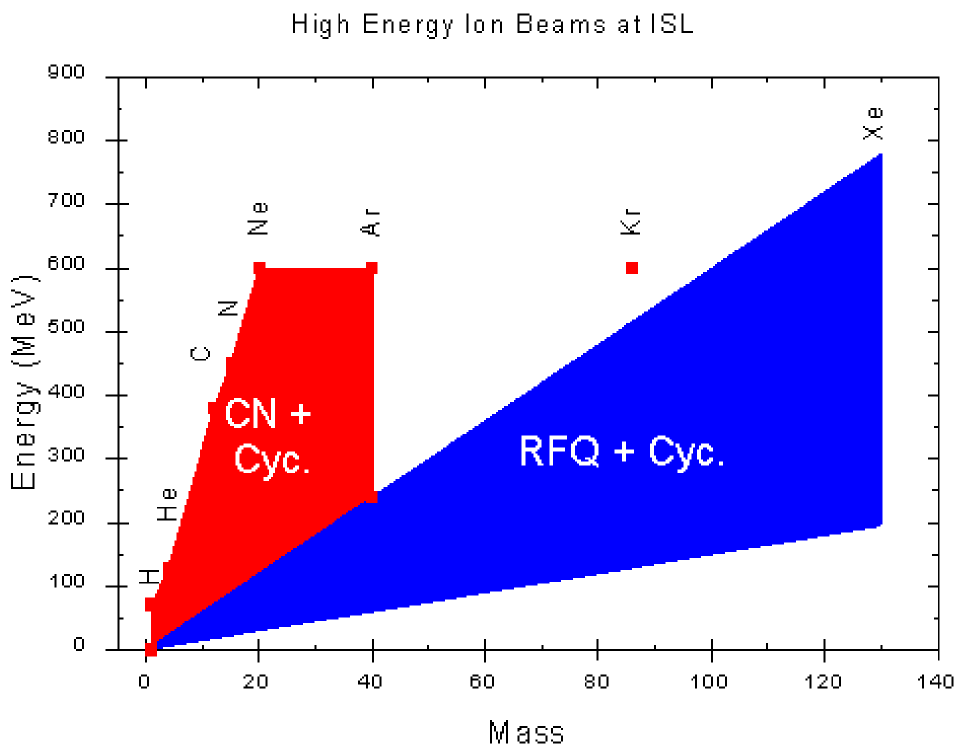
- a Facility for Users of Ion Beams -

Ion beams are an important and unique tool for modern science and technology. At ISL, scientists find a broad spectrum of ion beams over a wide range of energies to meet their specific demands. They can either use installed target areas or install their own technical equipment.
ISL scientists and technicians offer their specific expertise resulting from a broad range scientific program in structural and materials research as well as from their involvement in a lot of technical applications of ion beams.
ISL is a large scale facility of the Forschungsverbund "Ionen und nukleare Sonden in der Festkörperphysik". Thus, it also offers excellent opportunities for young scientists.

Requests for beam time at ISL must be submitted to the programme advisory committee, which decides solely on the basis of the scientific importance of the project. The committee meets twice a year.

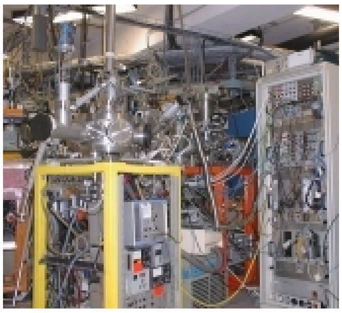
Beam Time Allocation Dates   Scheduled Beam Times

High Energy Beams at ISL:



Target Areas

The different target areas are equipped with specific experimental set-ups, for which the basic infrastructure, such as vacuum systems, beam diagnostics, cooling or heating systems, is installed. The topography of the facility also permits the installation of so-called dual-beam areas where samples can be irradiated with both high- (cyclotron beams with the RFQ-injector) and low- (Van-de-Graaff beams) energy beams simultaneously. In total, 15 target areas are in operation. These are for:

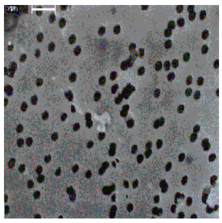


Ion Beam Analysis

- ERDA (Elastic Recoil Detection Analysis) with time-of-flight spectrometer
- ERDA with magnetic spectrometer
- RBS (Rutherford-Back-Scattering) instruments
- γ-target area for hydrogen profiling
- high-energy PIXE (Proton induced X-ray Emission)

Materials Modification

- irradiation of foils
- deep temperature area
- μ-metal chamber with electron spectrometer

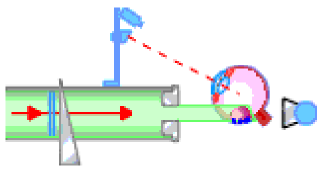


Short-lived radioactive probes

- Mößbauer spectroscopy
- two stations for PAD (Perturbed Angular Distribution)
- implantation for PAC (Perturbed Angular Correlation)

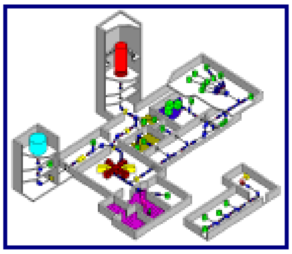
Medical Applications

- therapy of ocular melanomas



Other Applications

- vertical beam line, e.g. for liquid samples
- large, multi-purpose scattering chamber



Click on the graph for more details.

In addition, four stations are available for decelerated highly-charged ions.

The installations at the target stations are subjects to continuous change to meet the demands of new users and new experiments.

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Target Areas

Program Advisory Committee

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Programme Advisory Committee

Applying for beam-time at ISL-Berlin

All experiments at ISL Berlin are reviewed by a programme advisory committee (Benutzerausschuss, BA). The BA meets once a year for the distribution of beam-time on the basis of the proposals and oral presentations.

The last meeting of the BA took place September 30, 2005.

abridged version of the minutes:

"The requested beamtime for 2006 exceeds by far, as in the past years, the contingent provided by ISL. The BA regrets greatly the decision of the supervisory board of the HMI to close ISL at the end of 2006. For a large part of the user community this means the end of their existing research with ion beams, as many of the experiments performed at ISL cannot be transfered to other accelerators."

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Dates for ISL-Beam-Time Allocations

This table will is only offered as pdf-file. Please, contact the beam-time co-ordinator Dr. H. G. Bohlen if this does not meet your requirements.

ISL-Beam-Time-Allocations

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Scheduled ISL-Beam-Time

The following tables are offered as pdf-files only. Please, contact the beam time co-ordinator if this does not meet your requirements.

Actual Period

Next Period

Next but one Period

Please, contact Dr. H. G. Bohlen for questions concerning beam time allocation.

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ISL-Info Archive

ISL-Reports

Annual Report 2004
Annual Report 2003
Annual Report 2002
Annual Report 2001

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ISL Info

New: June 2005
ISL Info No. V, 2005 (0.7 Mb)

Contents:
Editorial
Obituary Dr. H. Bertschat (in German)
Novel Ion Track-Based Electronic Structures, an Overview
Memorandum zur Ionenstrahlphysik - (in German)
and more

ISL Info No. IV, 2004 (0.3 Mb)

Contents:
Editorial
News from the secretary of the ISL program advisory committee
Interface Mixing in Ceramic Thin Layer Systems
Induced by Electronic Energy Loss of Swift Heavy Ions
New Proposals at ISL
and more

ISL Info No. III, 2004 (0.7 Mb)

Contents:
Editorial
Defect Annealing in Conventionally Predamaged GaAs and InP
due to Swift Heavy Ions
French-German Summer School "Tracks03"
New Proposals at ISL
and more

ISL Info No. II, 2003 (1.2 Mb)

Contents:
Editorial
Five Years Proton Therapy of Eye Tumours
Important Dates
and more

May 2003: ISL Info No. I, 2003 (0.4 Mb)

Contents:
Editorial
Intense High Energy Gold Beams for Solid State Physics at ISL
Informations from the Programme Advisory Committee
and more

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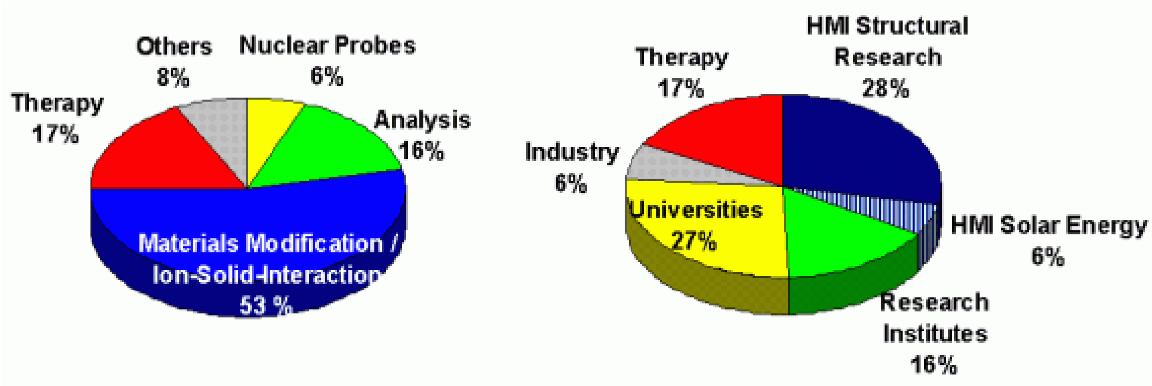
Operation and Technique

Beam Time Use in 2006:



ISL-Crew:

scientists:	A. Denker, W. Bohne, W. Busse, H. Homeyer, W. Pelzer, C. Rethfeldt, J. Röhrich,
engineers and technicians:	P. Arndt, M. Birnbaum, G. Brüning, J. Bundesmann, D. Draht, W. Hahn, D. Hildebrandt, M. Jung, U. Müller, J. Reinicke,
operators:	R. Grünke, G. Heidenreich, H. Lucht, E. Seidel, H. Stapel
tumour therapy:	D. Cordini, J. Heufelder, H. Kluge, R. Stark, A. Weber, plus S. Höcht, S. Runge (Charité, Universitätsmedizin Berlin) M. Fitzek (Universitätsklinikum Essen)

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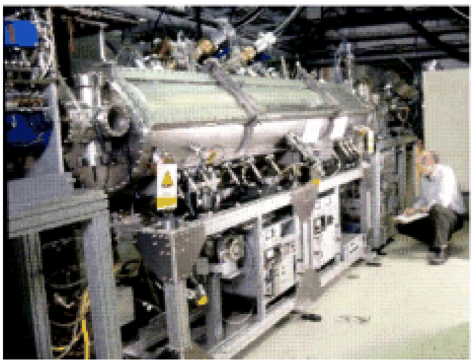
Accelerators at ISL

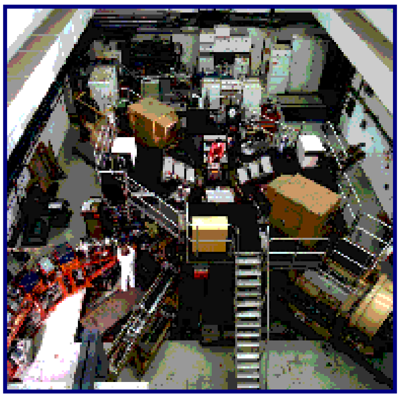
The accelerators at ISL are specifically chosen and designed to meet the various demands of the very heterogeneous community of ion beam users.

Ions with the lowest energy are produced with a special decelerator: Highly charged ions from the ECRIS4-Source are decelerated to some Volts shortly in front of the target. This results in a rather unusual ion species having high potential and low kinetic energy. They allow specific applications in surface analysis and surface treatment.

There are two accelerators for ions with higher energies. They are complementary in their specifications: The Van de Graaff delivers ions with an extremely high energy accuracy and energy resolution. The energy can be changed very rapidly. The terminal is equipped with a 5 GHz ECR-Source allowing a wide range of different charge states to be accelerated. Thus, a wide energy range can be offered for heavier ions. With these features the Van de Graaff is an excellent tool for materials analysis.



The RFQ-structure, has been developed for ISL. With its ECR-Source on a 200 kV high voltage potential it is capable to deliver ions practically over the whole periodic table, for masses up to about 100 amu with very high beam currents. Thus, it is the ideal machine when high dose rates are requested.



The Cyclotron is the ISL's most important installation, and produces the highest ion energies. It is an energy amplifier with a fixed factor of 17. With its variable high frequency and magnetic field, its energy variation ranges from 1 MeV to 70 MeV per ion-mass unit. The ISL cyclotron produces a quasi-continuous beam with a micro-structure, having a pulse width of less than 0.5 ns and a frequency of 10 MHz-20 MHz. This time structure combines the advantages of a continuous beam for irradiations with the possibility of using pulsed beams. This variety and combination of ion-beams, ion-energies and beams-structures is unique in Germany.
The high ion-energies delivered by the cyclotron, make possible a wide range of applications. These extend all the way from eye tumour therapy, with very fast, deeply penetrating protons; to the production of short-lived isotopes, using relatively light- to intermediate-mass ions; to plastic deformations of materials with extremely heavy ions.

Ion Sources

ISL exclusively operates ECR (Electron Cyclotron Resonance) ion sources. A plasma confined by a radial hexapole and an axial dipol field is heated by microwaves to produce highly-charged ions. The microwave frequency is chosen to fulfill the cyclotron resonance conditions for electrons in the central region of the plasma. The different ECR ion sources run with different RF frequencies and RF power.
ECRIS4 is the most powerful source. It is operated at ground potential. The longitudinal magnetic field is formed by electromagnets. It offers the highest tuning capacity and is used to produce very highly-charged ions.
The other two sources, the SUPERNANOGAN and BECRIS were designed to operate on high voltage platforms. Their magnetic fields are entirely configured from permanent magnets to reduce the electrical power requirements.

	Frequency	Magnetic Field	Consumption	Purpose	Accelerator
ECRIS4	14 GHz	10 kG El.Magn.	130 kW	highly-charged ions	Stand-alone Decelerator
Super-nanogan	14 GHz	10 kG Perm.Magn	10 kW	high currents Q/A 1/8-1/5	200 kV Platform
BECRIS	5 GHz	3 kG Perm.Magn	1 kW	highly-charged light ions	5.5 MV Van de Graaff
HF				p, d, He	2 MV Van de Graaff

Electron Cyclotron Resonance Ion Source