News of the EPOS Project at the ELBE Radiation Source in the Research Center Dresden-Rossendorf

EPOS-Team & R. Krause-Rehberg

- Extended Concept of EPOS
- Progress of the mono-energetic Positron Beam (MePS)
- Gamma-induced Positron Spectroscopy (GiPS)
- Digital detector system
Extended Concept of EPOS (ELBE Positron Source)

**MePS**
*Monoenergetic Positron Spectroscopy*
- Cave 111b / Lab 111d
- monoenergetic (slow) positrons
- pulsed system
- LT, CDBS, AMOC
- Still under construction

**CoPS**
*Conventional Positron Spectroscopy*
- LT, CDBS, AMOC
- using $^{22}$Na foil sources
- He-cryostat
- automated system
- digital detector system

**GiPS**
*Gamma-induced Positron Spectroscopy*
- Cave 109 (nuclear physics)
- Positron generation by Bremsstrahlung
- Information in complete bulky sample (up to 100 cm$^3$)
- all relevant positron techniques (LT, CDBS, AMOC)

Information Depth:
- MePS: 0…5 μm
- CoPS: 10…200 μm
- GiPS: 0.1 mm …5 cm
Ground plan of the ELBE hall

Accelerator Hall

Free Electron Laser (IR)

Neutron TOF Experiments

Positron Production

Bremsstrahlung

RF-generators

Experiment Control

Accelerator Electronics

GiPS

MePS

IR Laboratories

Martin-Luther-Universität Halle
Progress of Mono-energetic Positron Beam

- 40 MeV, 1 mA, 26 MHz repetition time in cw mode; lifetime, CDBS and AMOC with slow $e^+$
- Retain original time structure for simplicity and best time resolution
Electron-Positron Converter is finished
Still waiting for $\gamma$ Quanta in Lab ...

- Problem: 10 x 2 steering coils must be adjusted
- automatic LabView program is looking for annihilation gamma at end of beam line
Test of Beam Guidance with an Electron Source
Bremsstrahlung-induced highly penetrating probes for nondestructive assay and defect analysis

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Advantages
- information depth 0.1 … 5 cm; whole sample
- ideal for bulky samples (NDT), liquids, gases, biological objects, coarse powder, dispersions …

Disadvantages of slow LINACs
- Use of “normal” LINAC with 200 Hz has the problem of high gamma flux in only very few bunches
- Count rate very low, thus no coincidence techniques applicable such as CDBS or AMOC
- Peak / BG ratio bad (1:1)
- no lifetime spectroscopy possible

All this disadvantages can be overcome by use of a superconducting LINAC with > 10 MHz
Bremsstrahlung Gamma Source of ELBE (FZ Dresden-Rossendorf)

- Pulsed gamma source using superconductive Linac ELBE
  - repetition frequency 26 MHz (or smaller by factor $2^n$) in CW mode!
  - bunch length < 5 ps
  - up to 20 MeV (we used 16 MeV), no activation of samples by $\gamma$-n processes was found
  - average electron current 1 mA = 20 kW beam power; electron beam dump outside lab
    - thus gamma background at target position is very low (Ge detectors with 100% efficiency)
- Ideal for GiPS! Is now part of EPOS project – user dedicated positron source.
Setup extended by BaF$_2$ detectors for lifetime measurement

- 3 coincident setups were used: 2 AMOC and 1 CDBS spectrometer
- only coincident detection ensures high spectra quality

Problem
- all scattered quanta appear within positron lifetime – time coincidence alone does not reduce background at all
- but distance helps: for 2 x 511 keV quanta in coincidence the distance dependence is proportional to $r^{-2}$
- for arbitrary scattered gamma it is $\propto r^{-4}$

AMOC: Age-Momentum Correlation
CDBS: Concidence Doppler-Broadening Spectroscopy
The GiPS setup includes 6 Detectors (4 Ge and 2 BaF₂)
Single-channel Ge Spectrum of annealed Fe

- count rate about 20 kHz (200 kHz would be theoretically possible); total counts in example: 8x10^6
- about 50% of intensity in 511 peak of annihilation line
- decrease below 350 keV due to 5 mm Cu absorber plates in front of Ge detectors
- detection with analog electronics
Comparison annealed and deformed Fe

- expected behavior
- curve of deformed Fe is distinctly taller due to open-volume defects and thus increased fraction of annihilation with valence electrons (small energies – small Doppler shift)
Coincident lifetime spectrum: annealed Fe

- Here coincidence with Ge detector
- Spectrum is projection to the time scale of AMOC spectrum
- Count rate for AMOC spectrum = 320 /s
- One spectrum in 2h
- Time resolution = 210 ps
- BG/Peak = 1.7 x 10^-5
- 350 ps & 1.5 ns: annihilation at vacuum tube (polyethylene)
Residuals of fit show perfect fit

• analysis by LT 9.0 (J. Kansy)
Comparison: GiPS spectrum with conventional measurement

- same sample material – almost same statistics, similar time resolution
- conventional measurement with $^{22}$Na source 20 µCi (0.7 MBq) in sandwich geometry
- advantage of periodic positron source is obvious: background distinctly reduced
- result of spectra analysis is the same: 107 ps (bulk value for Fe; corresponds to literature)
Comparison annealed and deformed Fe

- two mechanically identical samples were prepared
- Fe annealed (1100°C; 2h in vacuum) and Fe (50% thickness reduction by cold rolling)
- spectra were easily decomposed
- expected results: annealed sample – one component 107 ps; deformed sample has 158 and 401 ps (dislocations and small vacancy clusters)
AMOC spectrum of annealed Fe

- AMOC: measurement of momentum of annihilating electron as function of positron age
- AMOC detection is not an extra gimmick, but is required to maintain quality of spectra
- only by coincident measurement of 511 keV annihilation line: suppression of scattered gamma (can be concluded from lifetime spectra)
Coincidence Doppler-Broadening Spectroscopy of Fe sample
• total count rate: \(5 \times 10^5\)
• no such visible deviations on \(t < t_0\) like for Fe (due to much smaller gamma scattering compared to Fe)
Amorphous Silica Glass

- round piece 1.5 cm thick, about 5 cm³
- lifetime spectrum: total count rate: $2 \times 10^6$
- same sample was measured conventionally in 1978 also in the same institute (former ZfK Rossendorf):

  151 ps - 523 ps - 1.57 ns (FWHM ≈ 350 ps)

G. Brauer et al., Appl. Phys. 16 (1978) 231

![Graph showing lifetime spectrum]

\[ \tau_1 = 147 \text{ ps} / 25.6\% \]
\[ \tau_2 = 522 \text{ ps} / 22.6\% \]
\[ \tau_3 = 1.61 \text{ ns} / 51.8\% \]
Many advantages:

• Pulse shape discrimination
• Exact time base
• extremely simple setup: nothing to adjust
• Timing routines now available
• Online computation using a Linux cluster
Workshop on Digital Signal Processing in Nuclear Science

http://positron.physik.uni-halle.de/EPOS/

Open-source Project
http://positron.physik.uni-halle.de/EPOS/Software/
Conclusions

- new concept of EPOS project is now extended to use mono-energetic Positrons (MePS), Gamma-induced (GiPS) and conventional spectroscopy (CoPS)
- all spectrometers are equipped with LT, CDB, AMOC
- fully digital system (in the future)
- EPOS can cover sample thickness range from 10 nm to 10 cm (7 orders of magnitude)
- MePS still under construction
- GiPS has been tested successfully
  - GiPS only possible because of the unique properties of the ELBE Linac (cw mode of 26 MHz intense and extremely short electron bunches, < 5ps bunch length)
  - background suppression by coincident measurement of Lifetime and Doppler (AMOC)
  - surprisingly good spectra quality
  - coincidence between 2 BaF\textsubscript{2}: resolution improves by 24% (FWHM = 160 ps)
  - problem: heating / cooling of sample because in holder positrons are also generated

Talk available at http://positron.physik.uni-halle.de