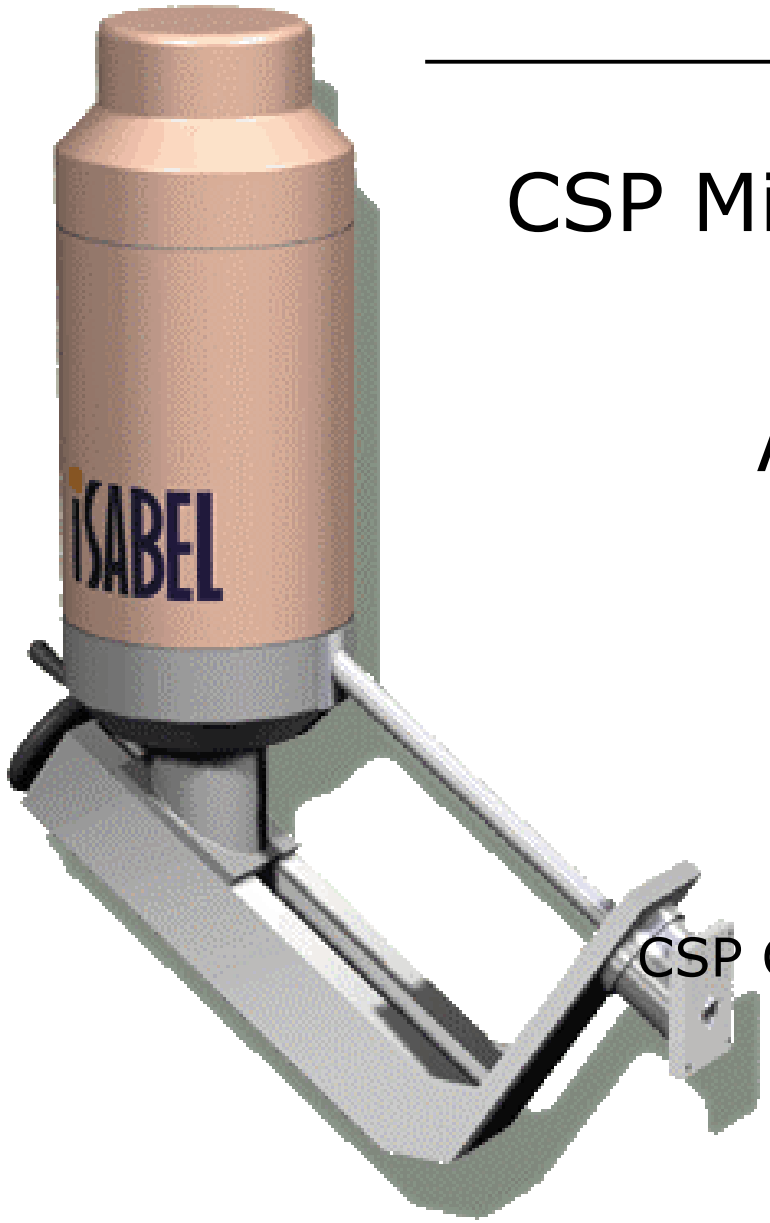


CSP Microcalorimeter X-ray Detectors

A status report

Jens Höhne

CSP Cryogenic Spectrometers GmbH

Ismaning, Germany

Overview

Cryogenic Spectrometers

- Who is CSP?
- Motivation
- Applications
- Technology
- Where do we stand now?

About CSP ...

Cryogenic Spectrometers

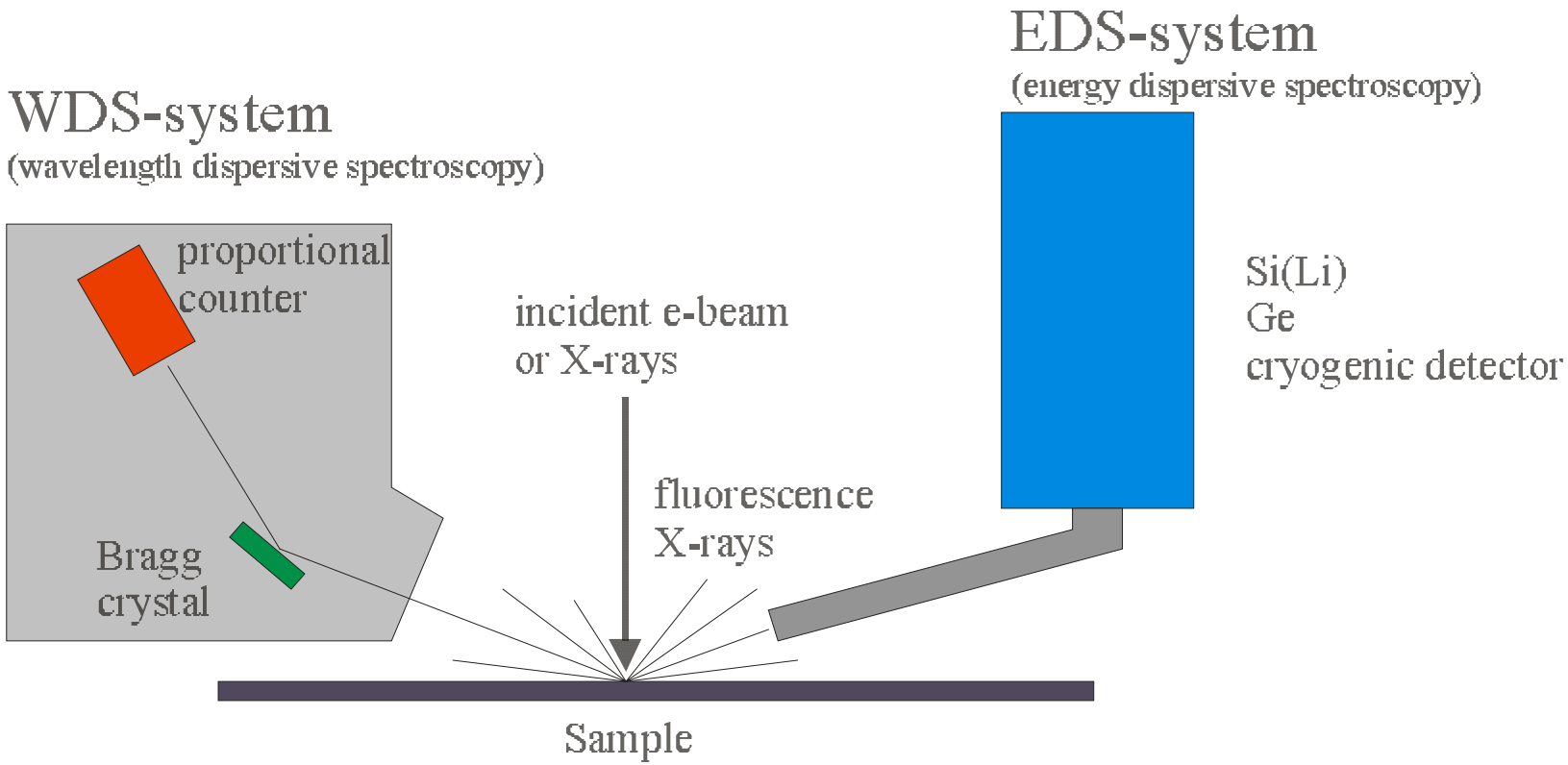
- Founded in 1998 by members of Technische Universität Munich and Max-Planck Instituts für Physik in Munich
- Personnel: 14 (8 in R&D)
- Location: Ismaning, close to Garching research campus
- Origin: astrophysics

CSP's products

- high resolution X-ray spectrometers
- Cryostat systems
- Consulting in
  - X-ray spctroscopy
  - Design of cryogenic systems
  - Applications of cryogenic detector systems

Motivation

Cryogenic Spectrometers

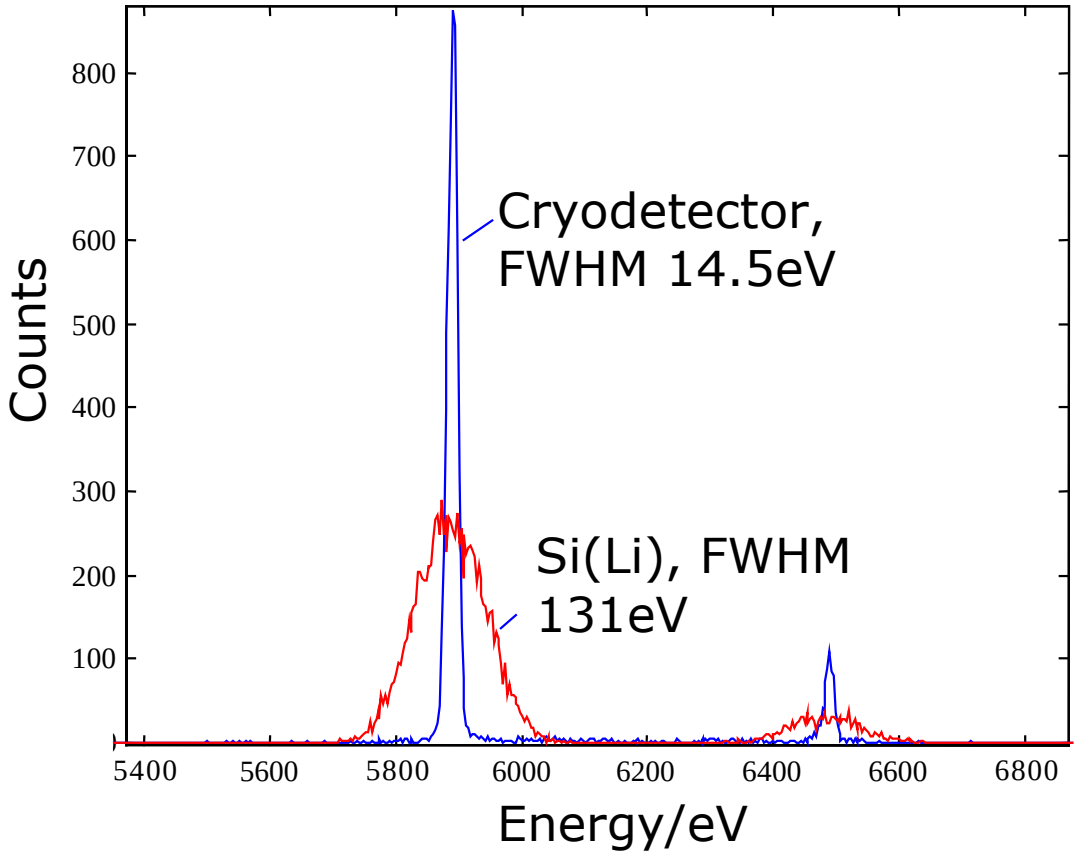


	WDS	EDS		
		Si(Li)	microcalorimeter	tunnel junction
Energy resolution	2 – 20 eV	120 eV → 170 eV	3 – 7 eV	4 – 15 eV
Count rate	> 50000	3000 → 100000	≈ 500	≈ 10000
Analysis mode	sequential	energy dispersive = all energies at same time		

Why to Use Cryodetectors?

- Better evaluation of low energy range in X-ray Spectroscopy, due to **better resolution**
  - > light element analysis
  - > low energy excitation,when small feature sizes are investigated
- Better determination of very light elements like Boron, due to **better signal-to-noise ratio**
- Higher sensitivity in UV-, VIS and mass spectroscopy, due to **better quantum efficiency**

Mn-K_α and Mn-K_β Peaks obtained with Cryo and Si(Li) Detector



Applications

Cryogenic Spectrometers

- Semiconductor industry
- Ceramics
- Radiation monitoring
- Biotechnology

Semiconductors

Cryogenic Spectrometers

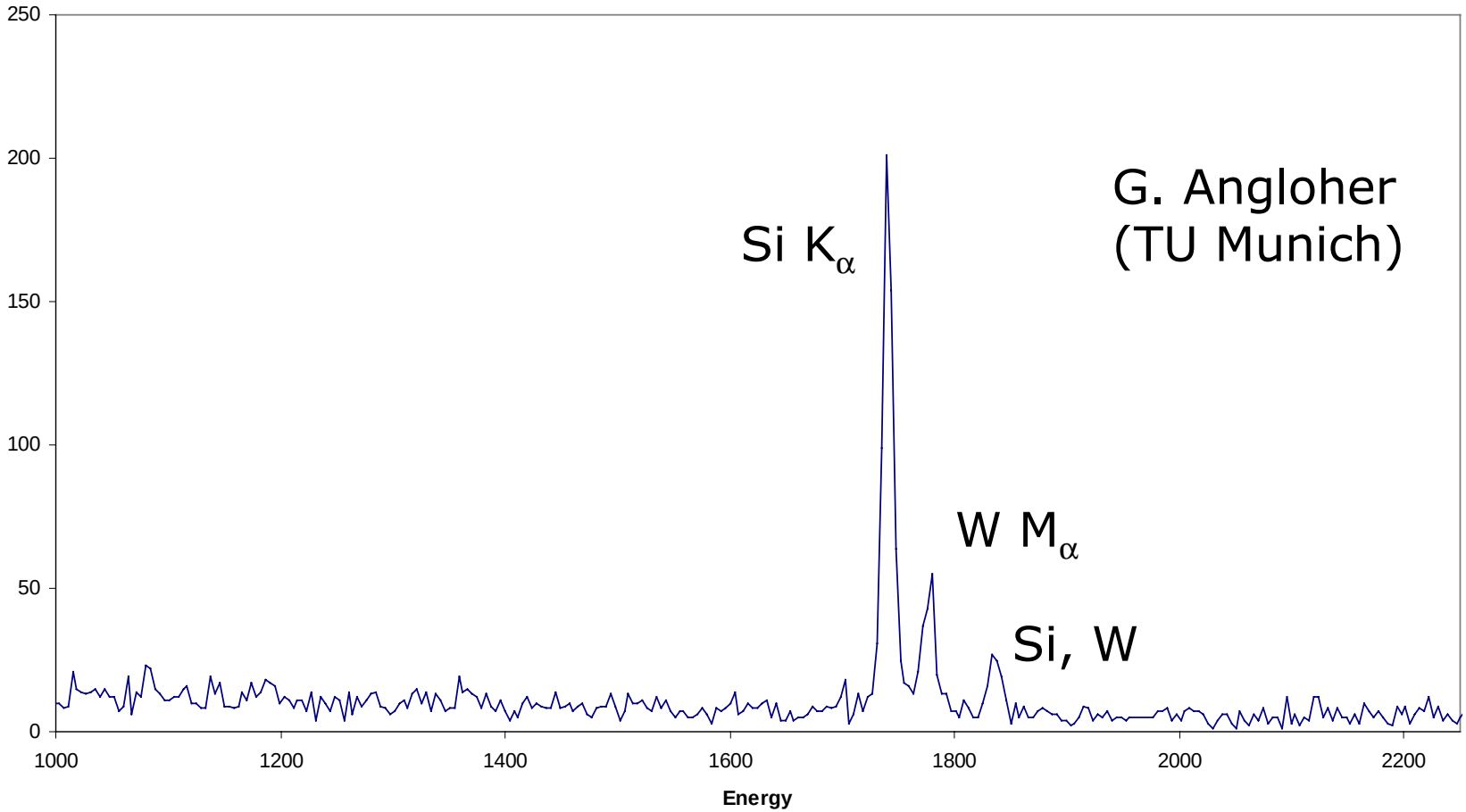
- high resolution X-ray spectroscopy
- particle identification

Semiconductor Applications

- System Ti/N (ΔE=60eV, Ti-Lα and N-Kα)
- System WSi_2 (ΔE=35eV, Si-Kα and W-M)
- Separation of Si-Kα, Ta-M and W-M ($\Delta E_{Si/Ta}$=30eV, $\Delta E_{Ta/W}$=65eV)
- Detection of elements with Z<10: B, C, N, O, F

Si & W

Cryogenic Spectrometers



Technology

Cryogenic Spectrometers

- superconducting tunnel junctions (STJ, NIS)
- superconducting transition edge sensors (TES)
- magnetic calorimeters

What limits energy resolution?

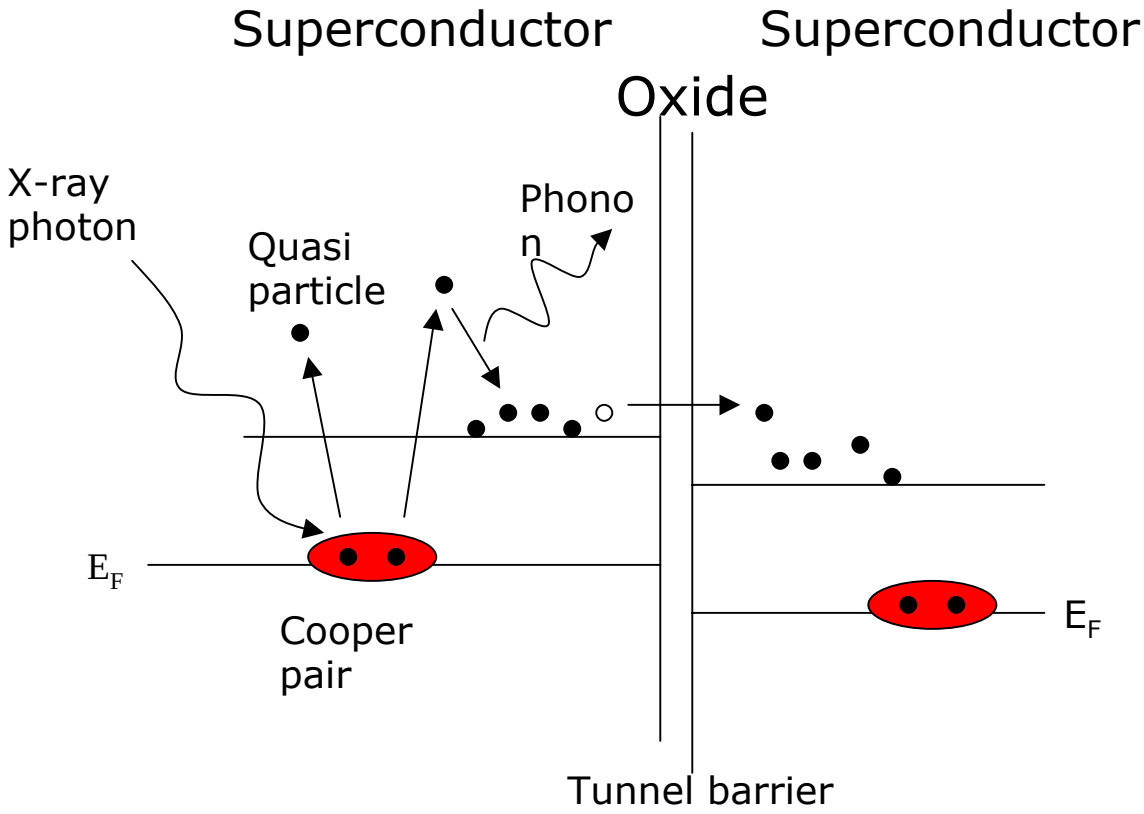
Cryogenic Spectrometers

Statistical limit: $\frac{\Delta E}{E} \propto 1/\sqrt{N}$

detector	**effective excitation energy**	**No of excitations (@ 6keV)**	**resolution @6keV**
proportional counter	30 eV	200	≈420eV
semiconductor	3 eV	2000	≈120 eV
low temperature detectors	10^{-5} - 10^{-3} eV	$>10^{6}$	< 6eV

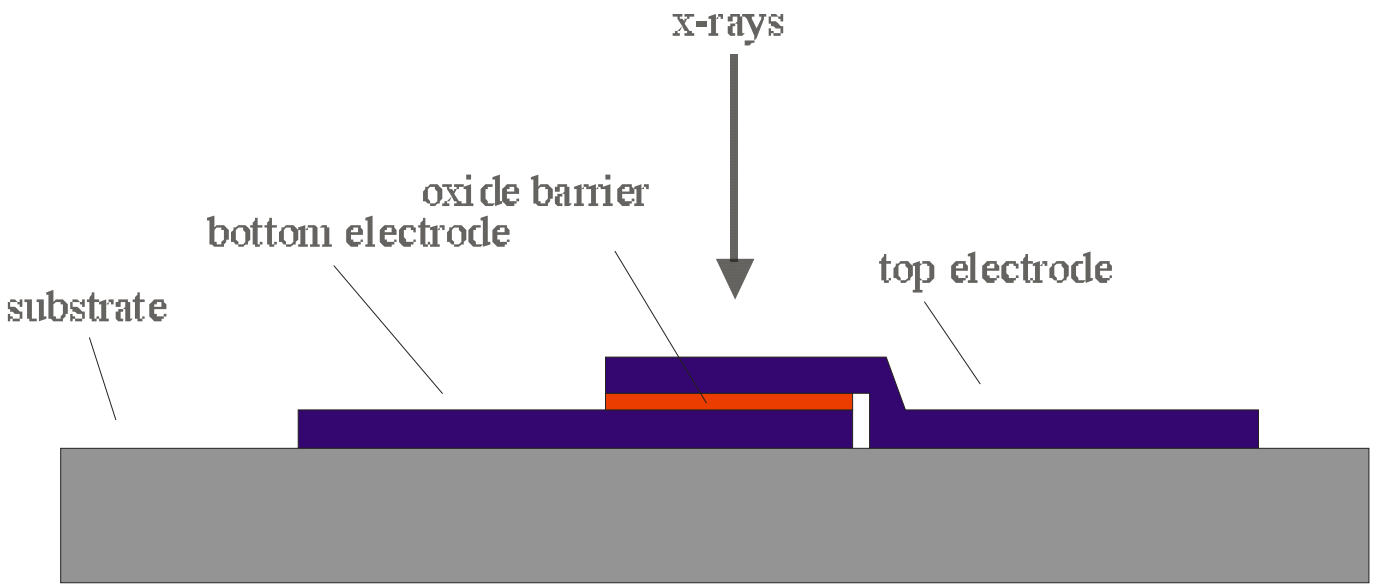
STJ

Cryogenic Spectrometers



Signal = current pulse

STJ



Materials used: Aluminum, Niobium, Tin, ...

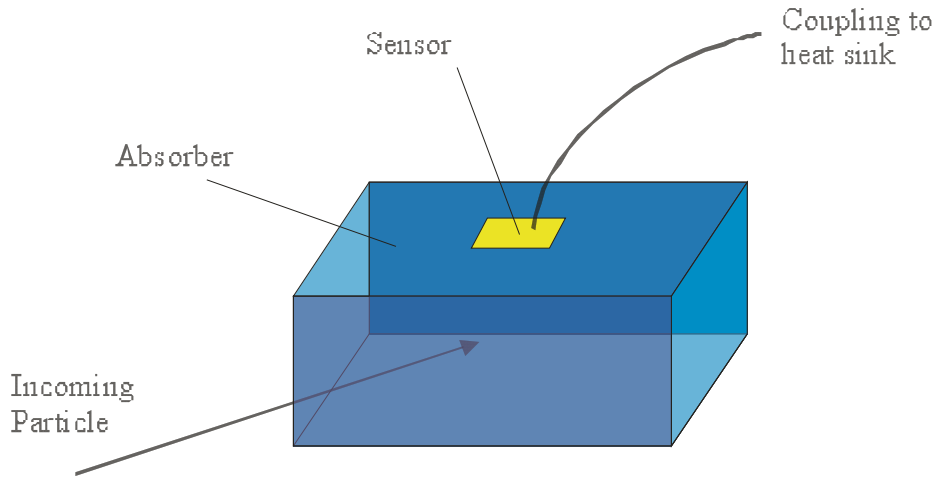
STJ summary

Cryogenic Spectrometers

- energy resolution < 20 eV
- high count rate > 10000cps
- area < 200um x 200 um
- magnetic field needed for operation
- double peak structure can be avoided using absorber

TES Microcalorimeter

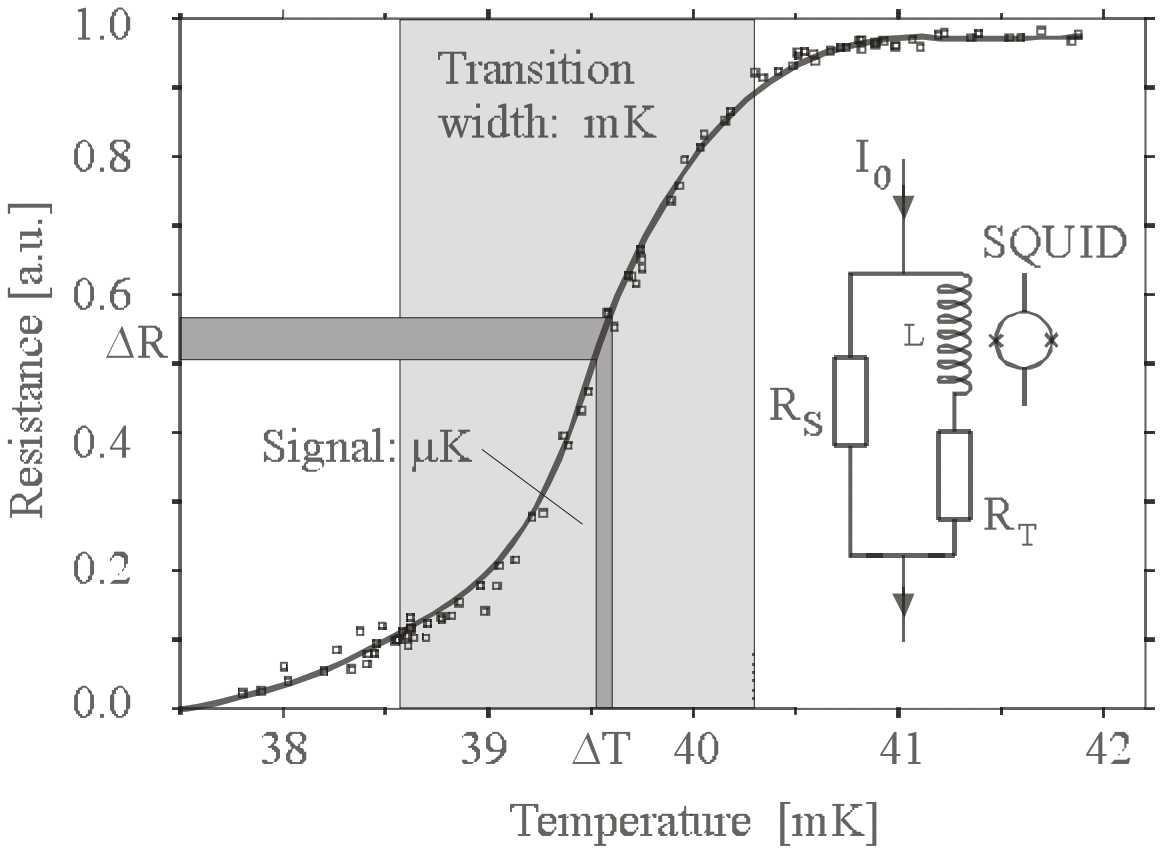
Cryogenic Spectrometers



temperature rise $\Delta T \propto \frac{E}{C}$

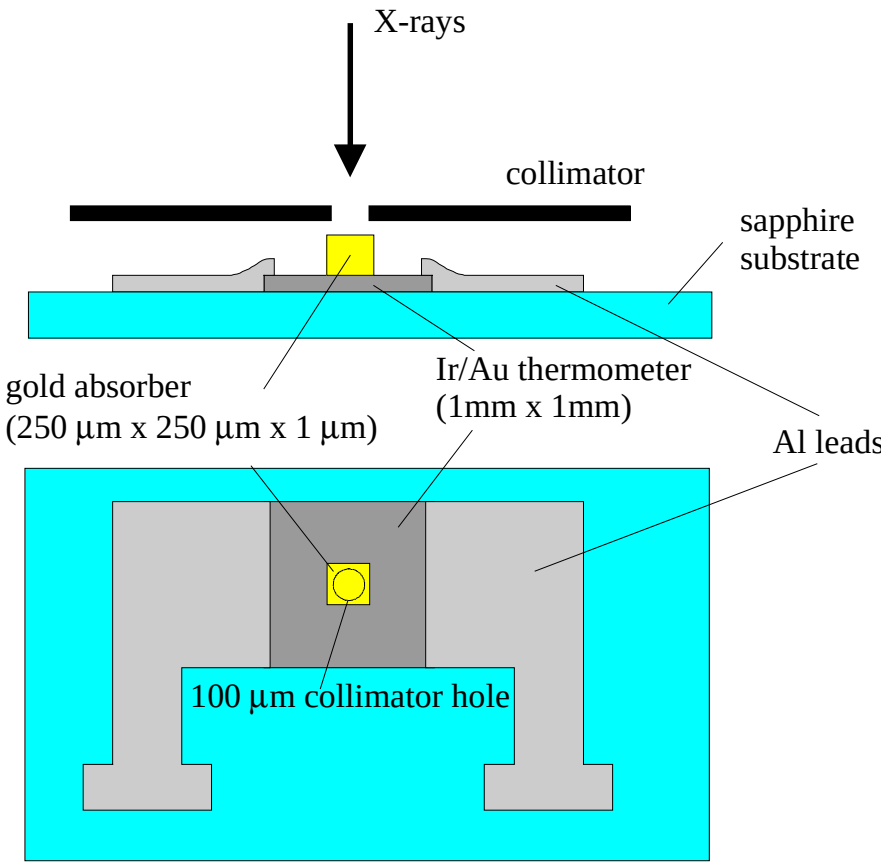
SPT / TES

Cryogenic Spectrometers



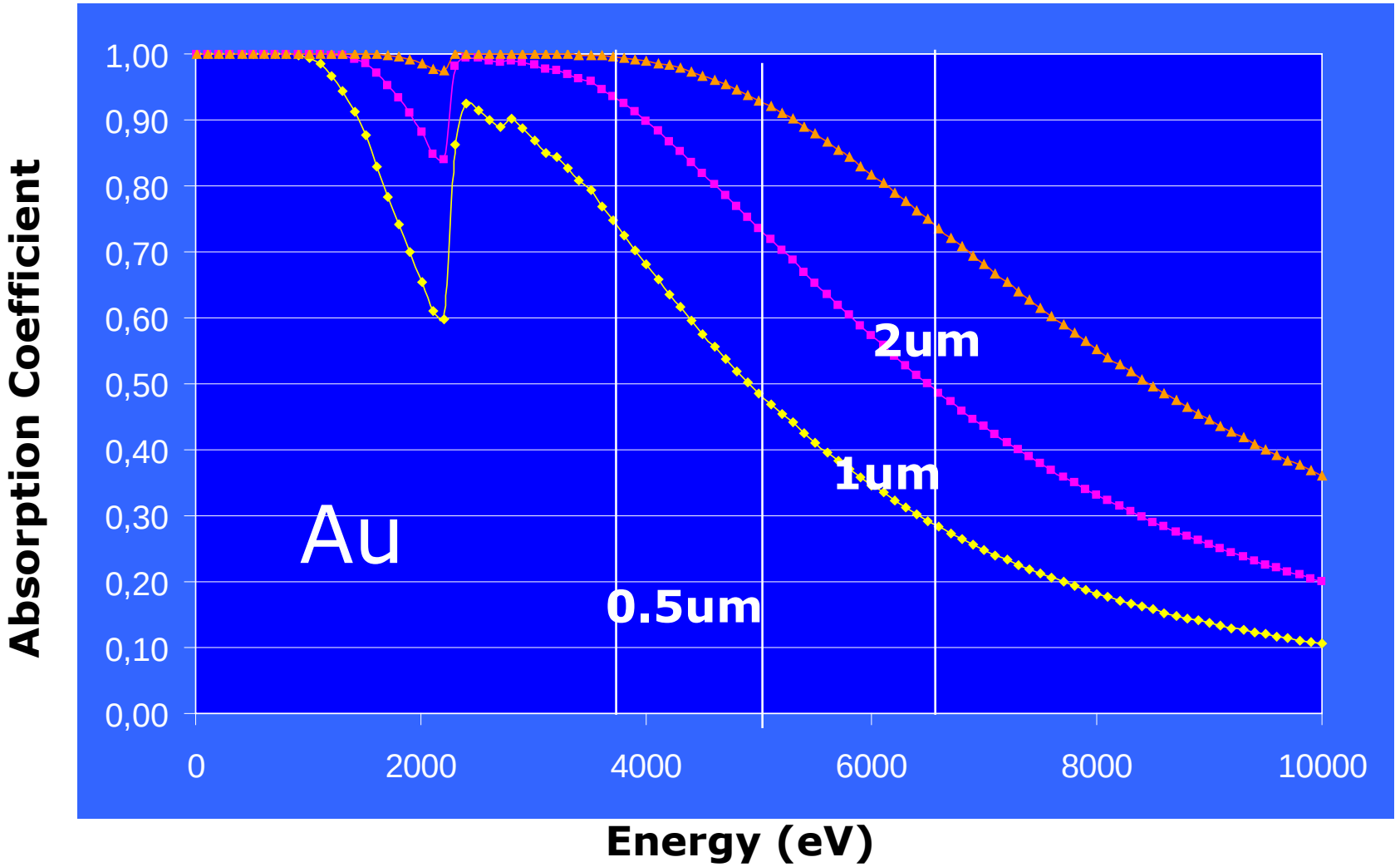
Microcalorimeter design

Cryogenic Spectrometers



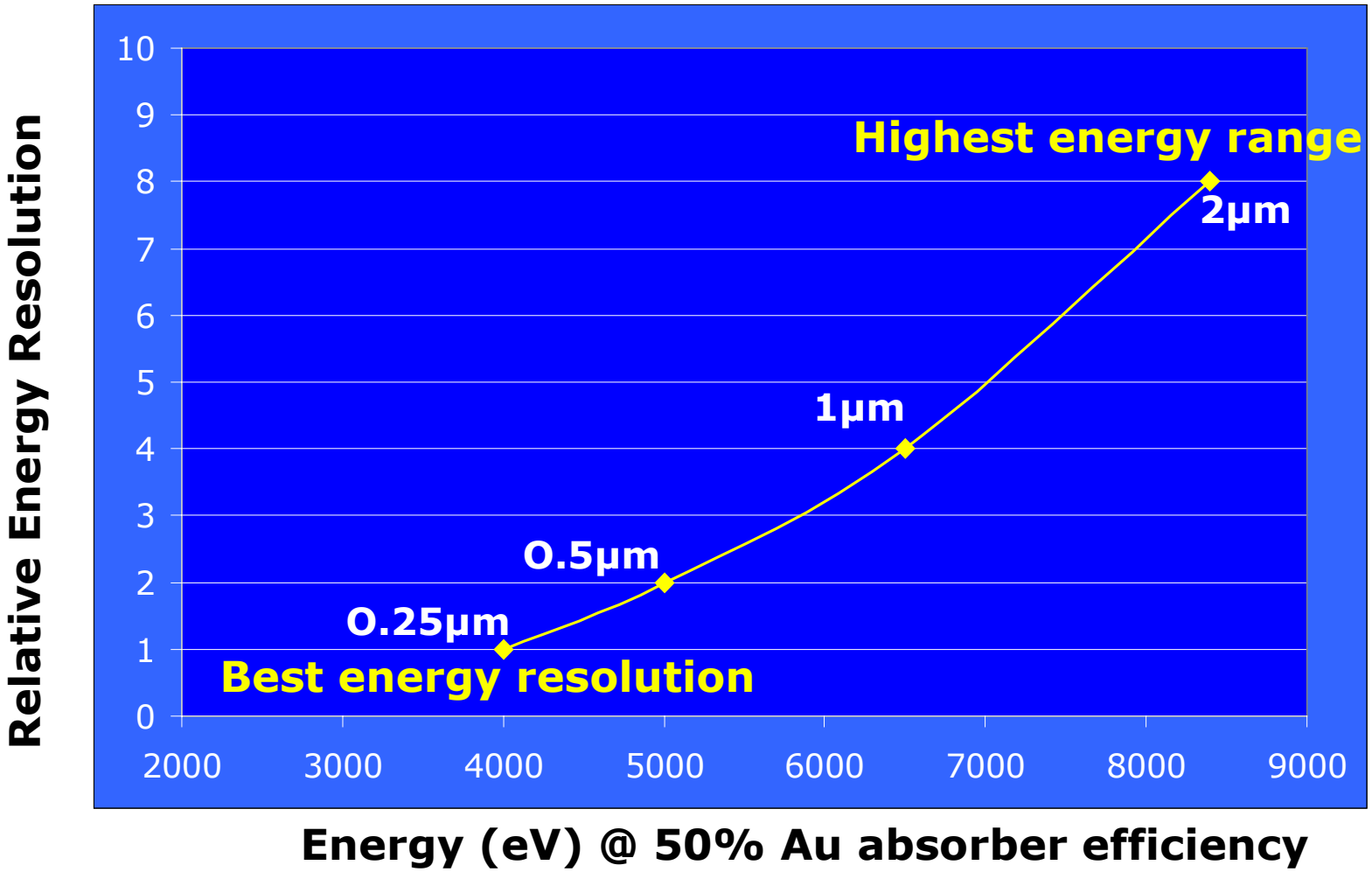
Absorption efficiency

Cryogenic Spectrometers



Energy resolution vs. absorption efficiency

Cryogenic Spectrometers



Microcal summary

Cryogenic Spectrometers

- energy resolution < 20 eV
- moderate count rate > 1000cps
- area < 400um x 400 um

- potential for even better energy resolution

Crucial issues

Cryogenic Spectrometers

- cooling (liquids vs. mechanical)
- solid angle (do we get count rate?)

Cryogenic system

Cryogenic Spectrometers

- temperatures around 100mK
  ➪ dilution refrigerator or ADR
- completely automized system
  ➪ no liquid coolants
- no vibrations
  ➪ no liquid coolants

Mechanical cooling

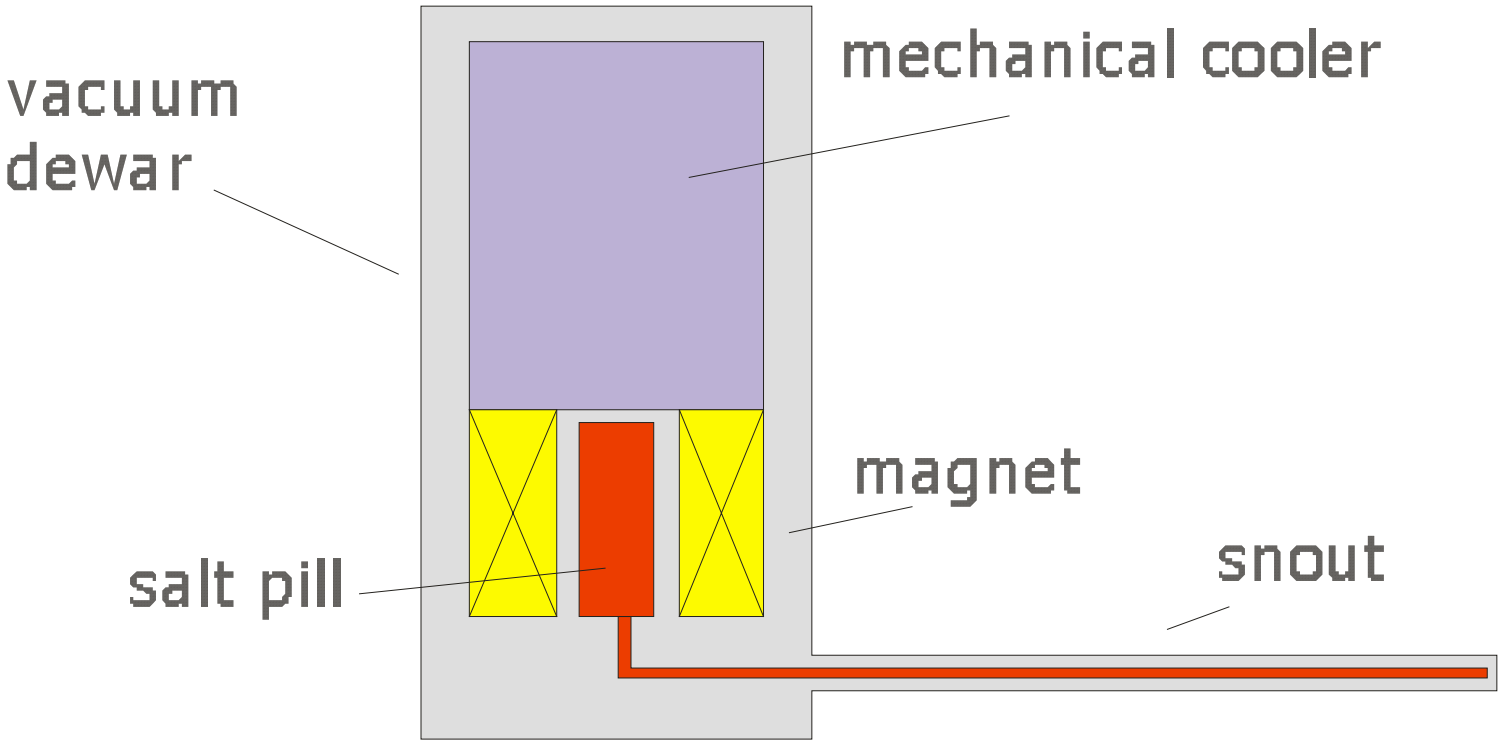
Cryogenic Spectrometers

- safety
- easy automation
- no manpower/storage needed

Are there vibrations?

Mechanical ADR

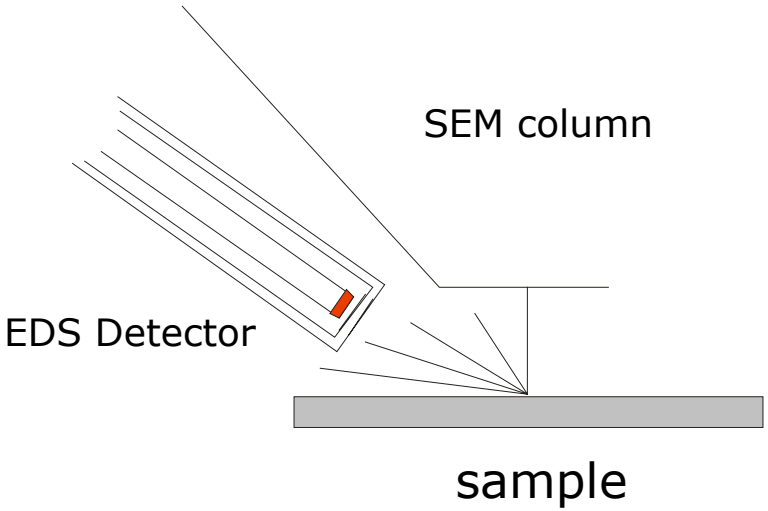
Cryogenic Spectrometers



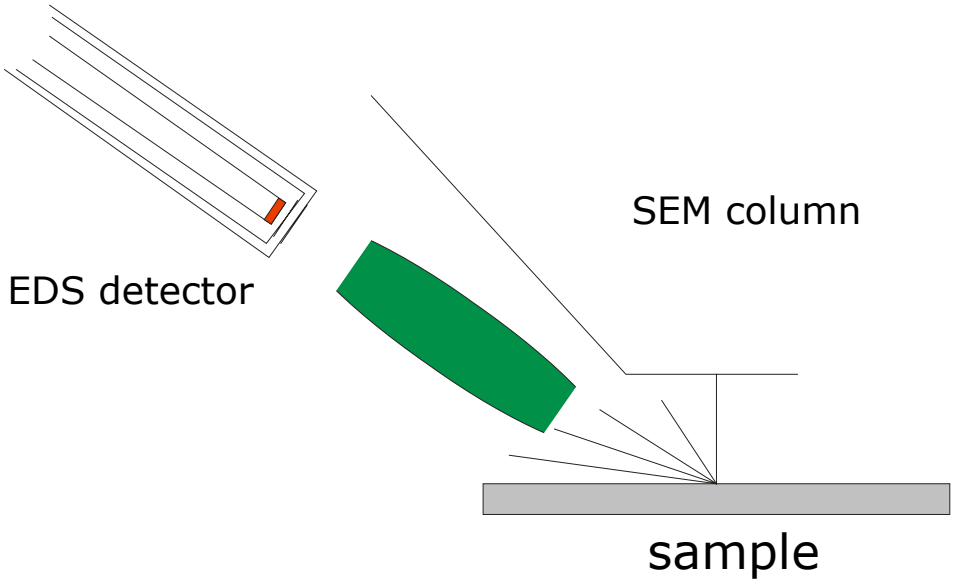
Solid angle

Cryogenic Spectrometers

Without polycapillary lens



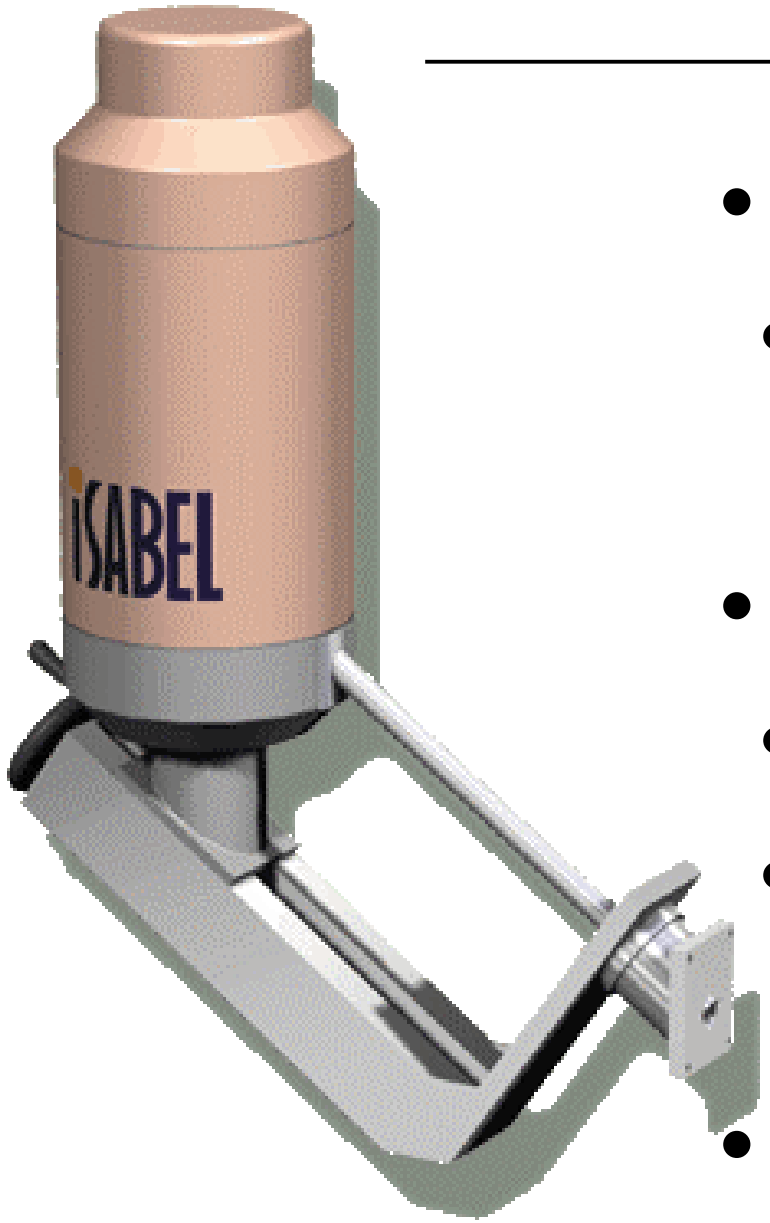
With polycapillary lens



- Increase in solid angle of **factor 100** is possible

Our product

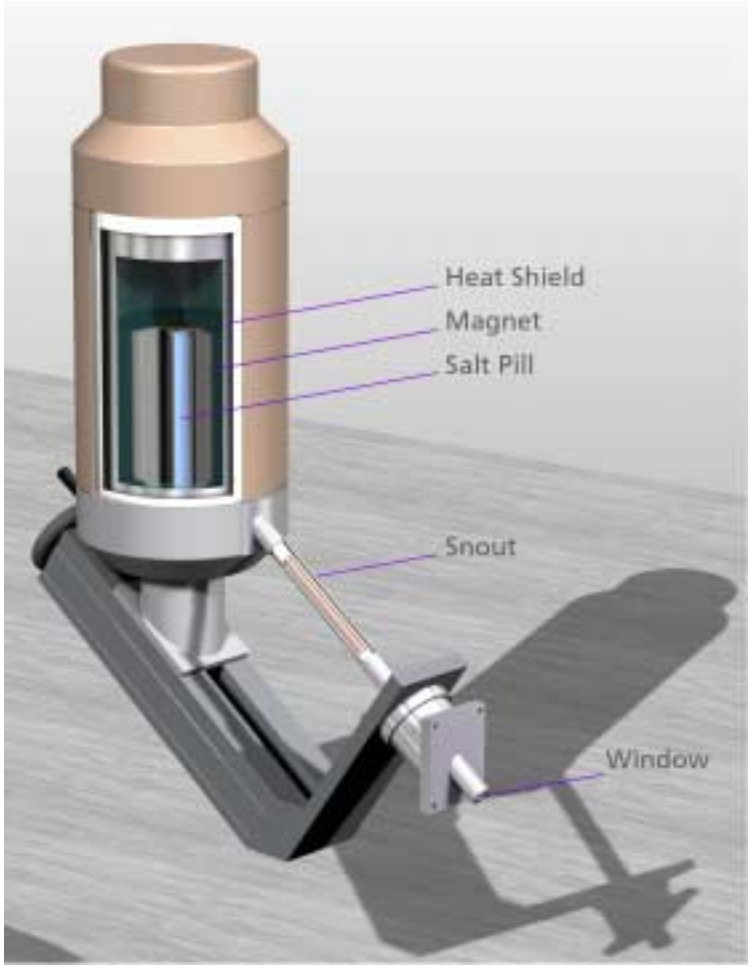
Cryogenic Spectrometers



- Spectrometer ISABEL
  - mechanically cooled
- Software package
  - elemental analysis
  - SEM Control
- Service and Support

...inside

Cryogenic Spectrometers



- 4K mechanical cooler
- 100mK ADR
- heat transfer inside snout
- detector @ 100mK

Objectives of CSP/ EDAX partnership

- Provide high performance, user-friendly microcalorimeter-based X-ray microanalysis system
  - Ease of use (no cryogens)
  - Self maintaining (>80 % duty)
  - Fine energy resolution over useable energy range
- Focus initially on application requirements of semiconductor industry
  - Small particle ID
  - Low energy spectroscopy @ fine resolution
  - Automated analysis

CSP / EDAX partnership

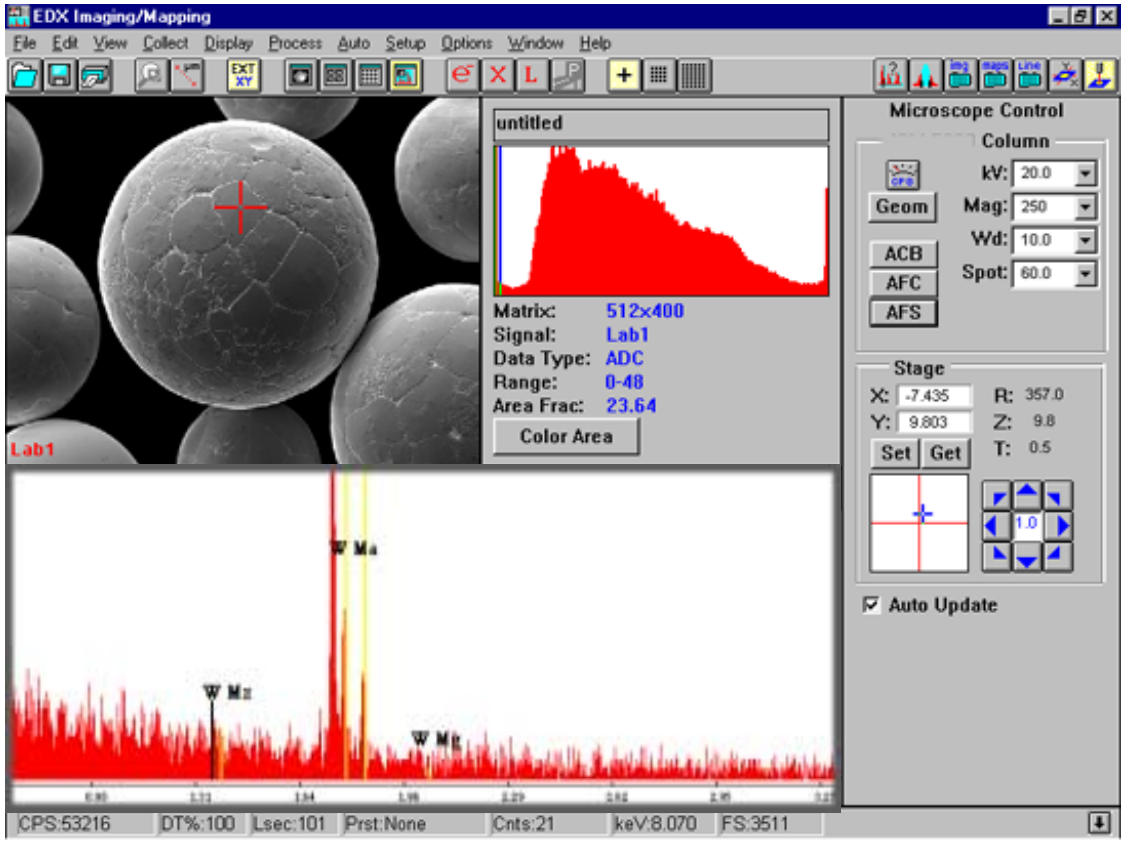
- Exclusive to microbeam applications
- proprietary CSP Detector & mechanical cooler technology
- EDAX „Phoenix“ analyzer platform
- Customer support teams combined worldwide

EDAX®
FIRST NAME IN MICROANALYSIS

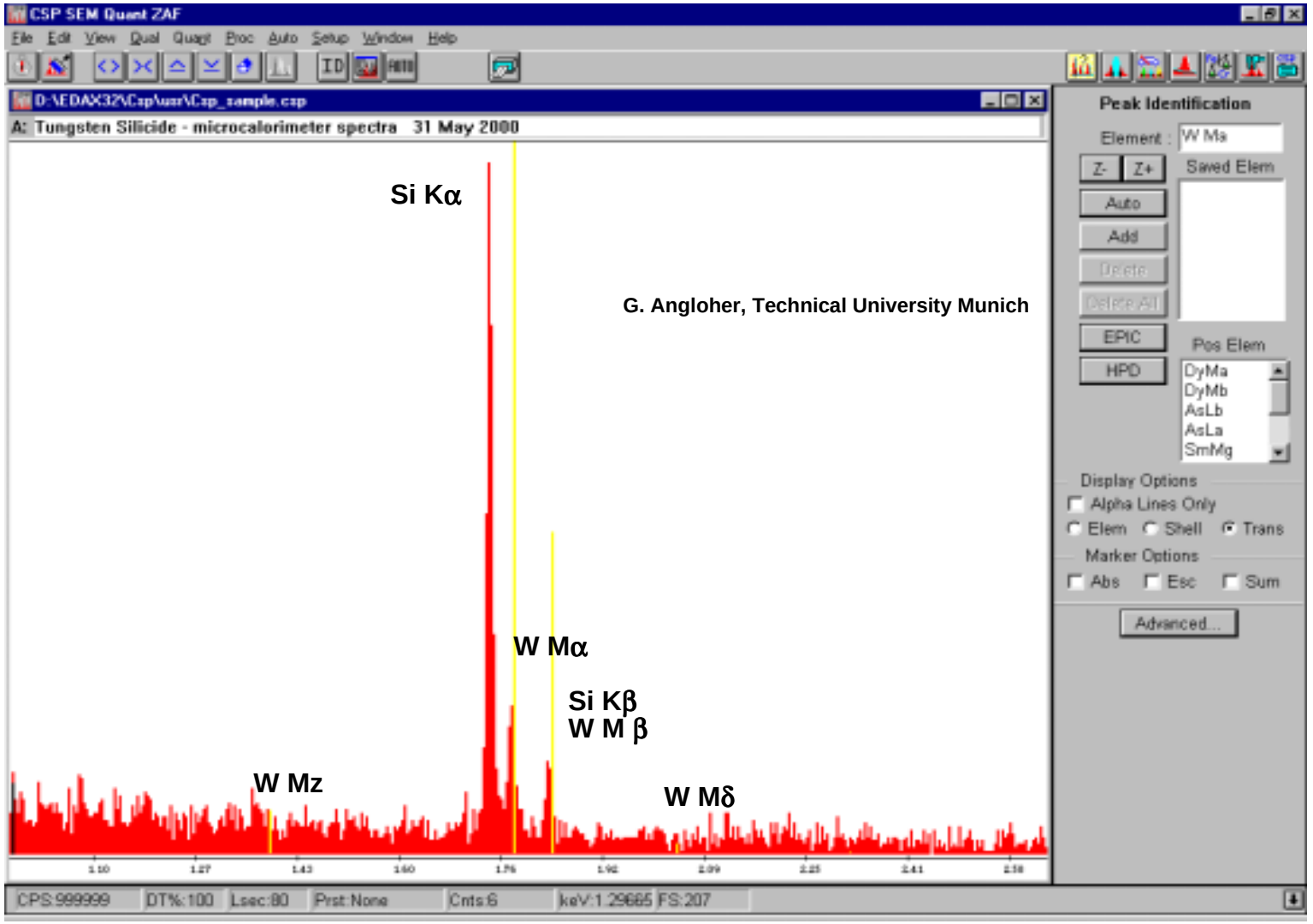
POLARIS

Cryogenic Spectrometers

CSP Microcalorimeter plus EDAX „Phoenix" Analyzer platform and full qualitative, quantitative and imaging software



Example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D:\EDAX32\Csp\usr\Csp_sample.csp
A: Tungsten Silicide - microcalorimeter spectra 31 May 2000
Si Kα
G. Angloher, Technical University Munich
W Mα
Si Kβ
W M β
W Mz
W Mδ
Peak Identification
Element : W Ma
Z- Z+
Saved Elem
Auto
Add
Delete
Delete All
EPIC
HPD
Pos Elem
DyMa
DyMb
AsLb
AsLa
SmMg
Display Options
Alpha Lines Only
Elem Shell Trans
Marker Options
Abs Esc Sum
Advanced...
CPS:999999 DT%:100 Lsec:80 Prst:None Cnts:6 keV:1.29665 FS:207

Conclusions

Cryogenic Spectrometers

- CSP have been developing a cryogen-free microcalorimeter X-ray detector
- Cooperation of EDAX and CSP will guarantee a commercial instrument based on expertise and experience
- Microcalorimeter will play a major role in existing future microanalysis applications