Status of Phase II Detector production TG02

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Reminder

- April 2006: 37.5 kg Enriched Germanium with 87% ^{76}Ge first delivered to Munich, now stored underground in the HADES UGL (Geel).
- April 2006: 50 kg of depleted GeO_2 also delivered to MPI is being used for purification and crystal pulling tests
- In 2007 new purification test started at PPM Pure Metals (Langelsheim, DE)
- June 2007: first test with depleted Ge completed
- October 2007: start of crystal pulling R&D contract with IKZ
- December 2007: a second purification test completed

Purification tests at PPM

- The first purification test at PPM Pure Metals GmbH (Langelsheim) was performed in May-June 2007.
- Second test August-December 2007
- Both tests were completed. The results are summarized in a report: GSTR-08-001
- After 3 steps of ZR total yield of 6N material 90%, no isotopic dilution effect, no dangerous contamination levels
- Solution was found for underground storage during purification
- Remaining 27kg of depleted Ge zone-refined at PPM (almost done)
- We are negotiating the reduction and zone-refinement of the enriched material

Crystal growing

Last meeting at IKZ 29.10.2008

- Since last collab. meeting 6 new crystals produced:
  - CZ4: from PPM material
  - CZ6: from 6N standard Ge
  - CZ7: The cleaner part of two previous crystals recycled
  - FZ-V3105: Float-zone crystal from PPM material
  - Ge-409: grown with a different Cz. puller
  - CZ8: from PPM material and using Ultra High Purity crucible
- They were all measured with Hall-effect and PTIS at IKZ

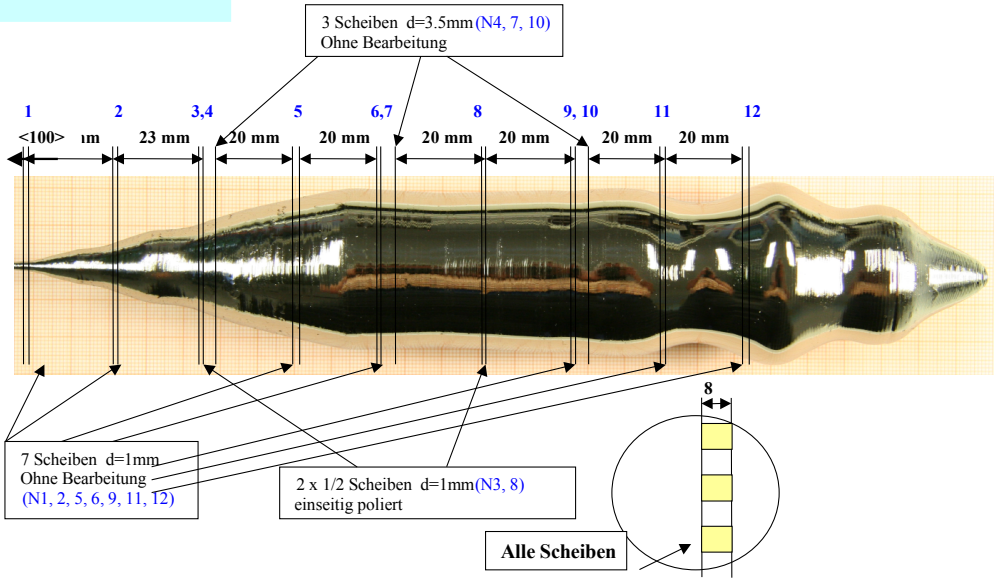
Crystal characterization

- CZ4 (PPM material) was cut every 2cm to produce a longitudinal impurity profile
- 2-3 samples cut from all other crystals
- Analysis completed:
  - All Cz. crystals have an impurity level typically of 10^{13}/cm^3
  - Float zone crystal seed end has 10^{11} impurity/cm^3
- Samples from CZ4 analyzed in Dresden with Photo-Luminescence spectroscopy
- Samples are prepared for further measurements at IKZ and Dresden

PPM –Material (3 experiments)

Crystal - CZ4 (Ge-HP-4)

Crucible – qsil PN
Atmosphere – Ar+2%H_2

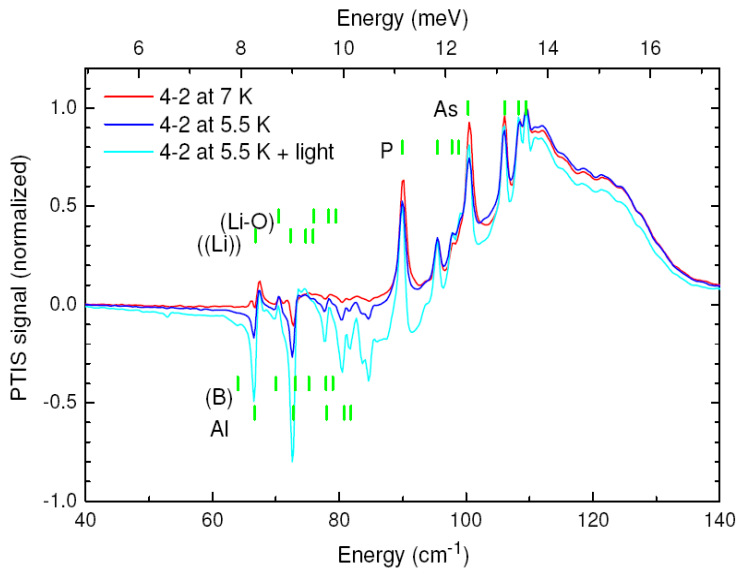


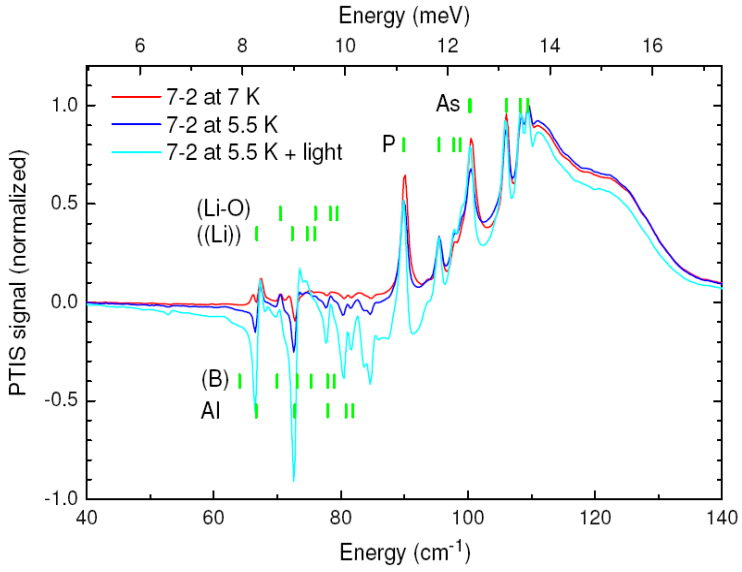
Conductivity and Hall effect results:

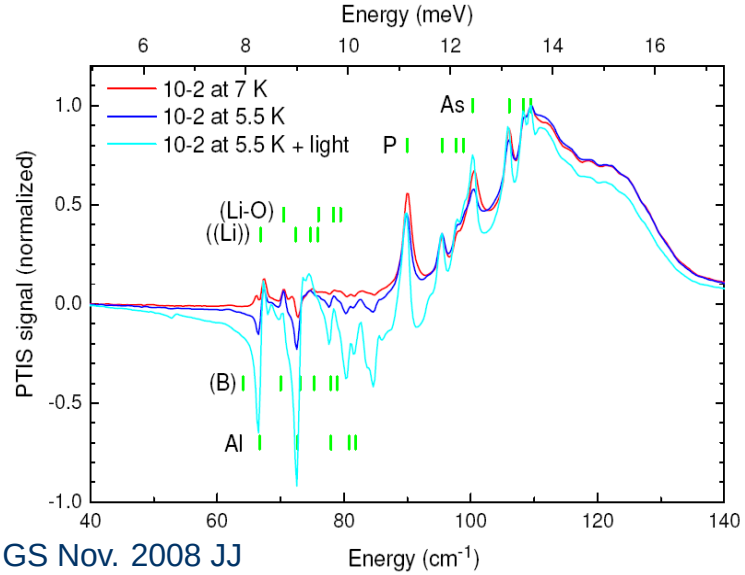
	Resistvity (Ωcm)		Electron conc. (10^{13} cm^{-3})		Mobility (cm^2/Vs)	
Temperature	***297 K***	***77 K***	***297 K***	***77 K***	***297 K***	***77 K***
CZ4_1-2	46.9	11.8	5.20	1.44	2561	36600
CZ4_2-2	51.6	11.5	4.14	1.50	2921	36090
CZ4_3-2	54.3	9.7	3.55	1.78	3238	36190
CZ4_5-2	44.2	7.8	4.60	2.22	3066	36120
CZ4_6-2	42.7	6.9	4.60	2.58	3182	35100
CZ4_8-2	30.2	4.3	6.36	4.11	3246	34970
CZ4_9-2	25.6	3.2	6.89	5.57	3539	34620
CZ4_11-2	13.4	1.6	12.3	12.24	3772	32170
CZ4_12-2	5.8	-	45.3	-	2366	-

Crystal - CZ4 (Ge-HP-4), PTIS

Photothermal ionization spectroscopy







Results

(i) The main donor impurities in this crystal are phosphorous and arsenic with a concentration ratio [P]/[As] ≈ 1 in sample 4-2 that seemingly changes to [P]/[As] ≈ 2 in sample 10-2. Additionally, there may be traces of lithium (isolated lithium donor and lithium-oxygen complex).

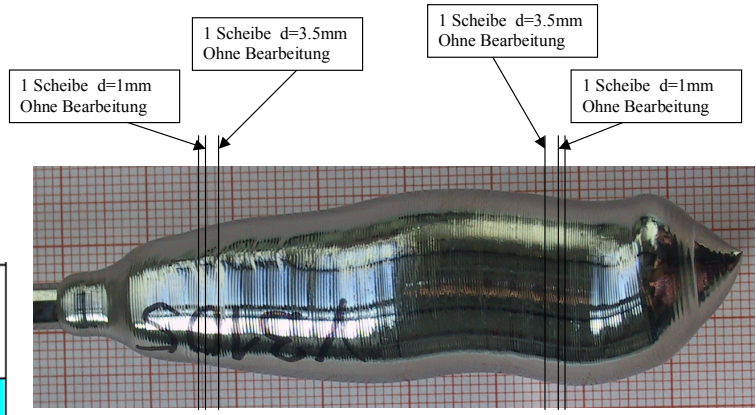
(ii) Compensating acceptors are aluminum and, to a much lesser extent, boron.

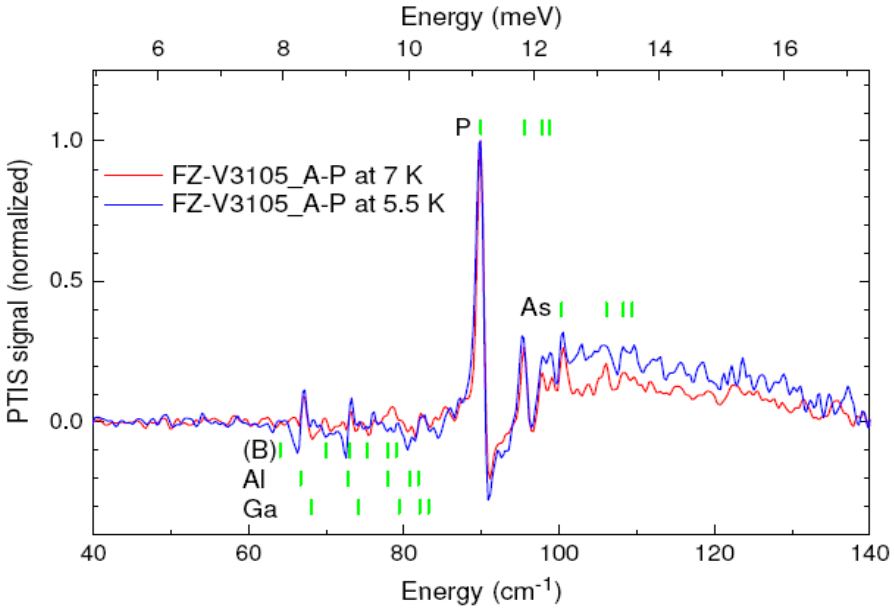
(iii) The net donor concentration N_D - N_A (= [P] + [As] + [Li] + [Li-O] - [Al] - [B]) increases from about 1.4×10^{13} cm^{-3} near the crystal's seed to 1.2×10^{14} cm^{-3} near the tail (sample 11-2).

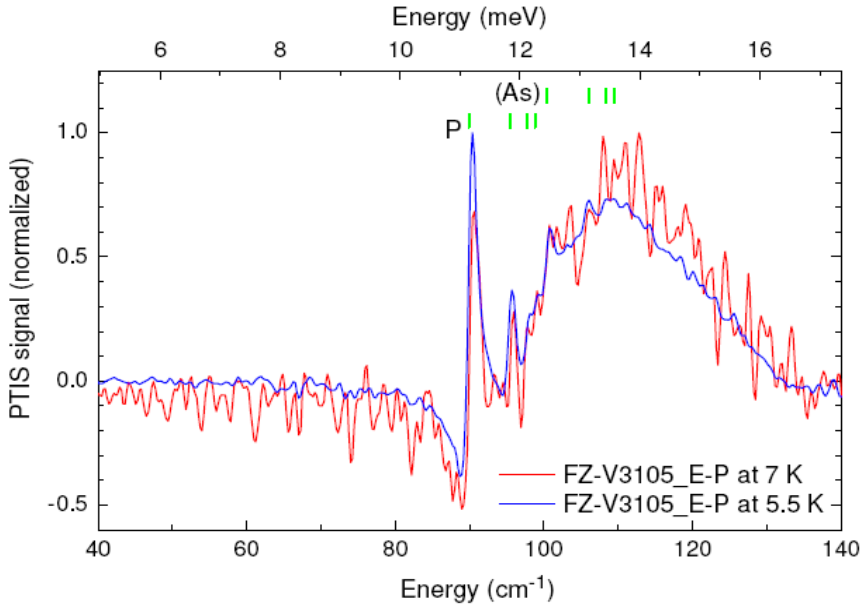
PPM –Material (3 experiments)

Ge-FZ-V3105

	Resistvity (Ωcm)		Electron conc. (10^{13} cm^{-3})		Mobility (cm^2/Vs)	
Temperature	297 K	77 K	297 K	77 K	297 K	77 K
Ge-FZ-V3105_A	57,9	3379	7,1	0,01	1569	25130
Ge-FZ-V3105_E	49	-	12,9	-	990	-





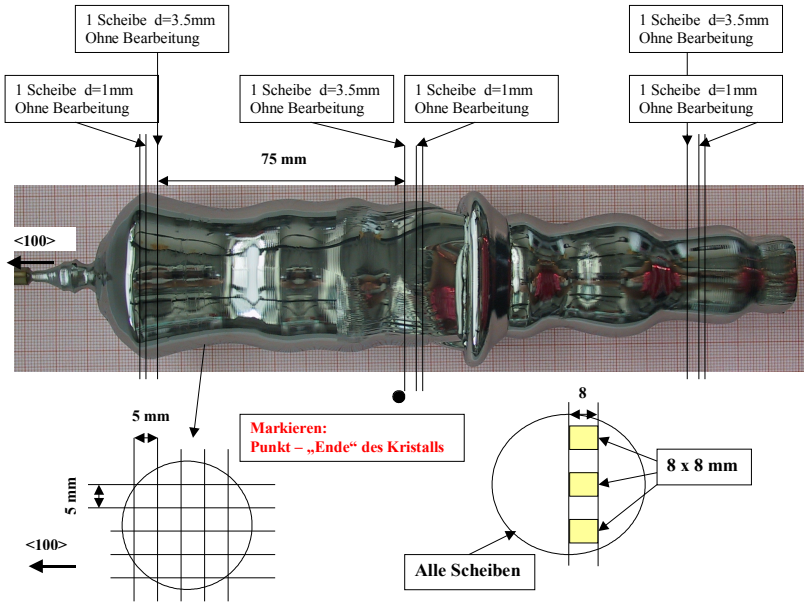


- main impurities: [P] >> [As], [Al], (traces of B, Ga)
- low concentration N_D-N_A = 1×10^{11} cm^{-3} near the seed
- no reliable Hall measurement at the crystal tail end up to now

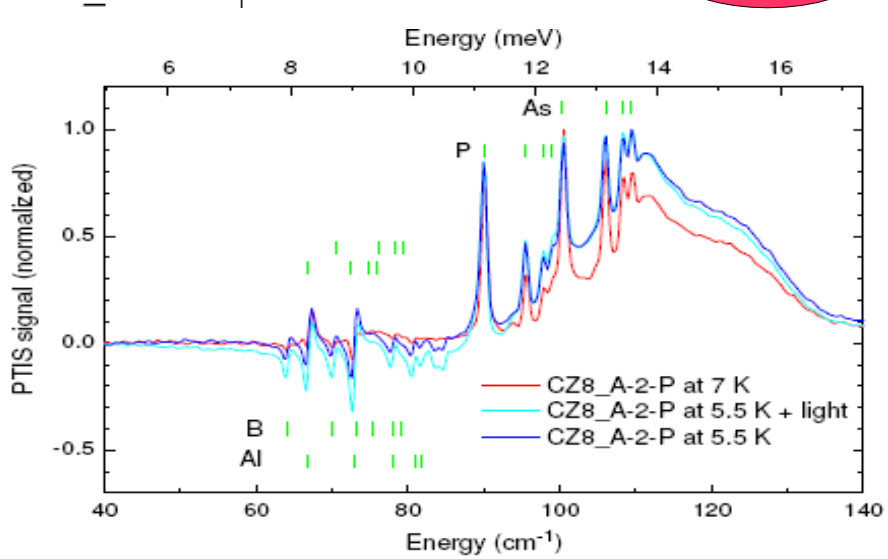
PPM –Material (3 experiments)

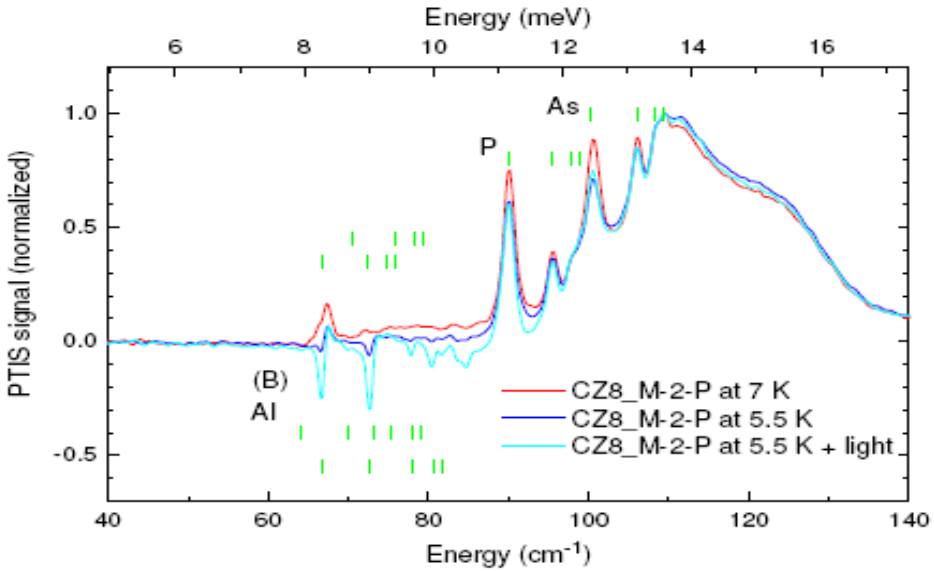
Crystal – CZ8 (Ge-HP-8)

Crucible – suprasil
Atmosphere – Ar



	Resistvity (Ωcm)		Electron conc. (10^{13} cm^{-3})		Mobility (cm^2/Vs)	
Temperature	297 K	77 K	297 K	77 K	297 K	77 K
Ge-CZ8_A-2	50,8	21,1	5,5	0,81	222	36500
Ge-CZ8_M-2	37,1	6,29	5,57	2.97	30[illegible]0	33400
Ge-CZ8_E-2	nicht messbar / elektrisch inhomogen!					





- main impurities: [P] ≥ [As]; [Al] > [B])
- N_D-N_A = 8×10^{12} cm^{-3} near the seed
- N_D-N_A = 3×10^{13} cm^{-3} near axial center
- no results near the tail due to electrical inhomogeneity

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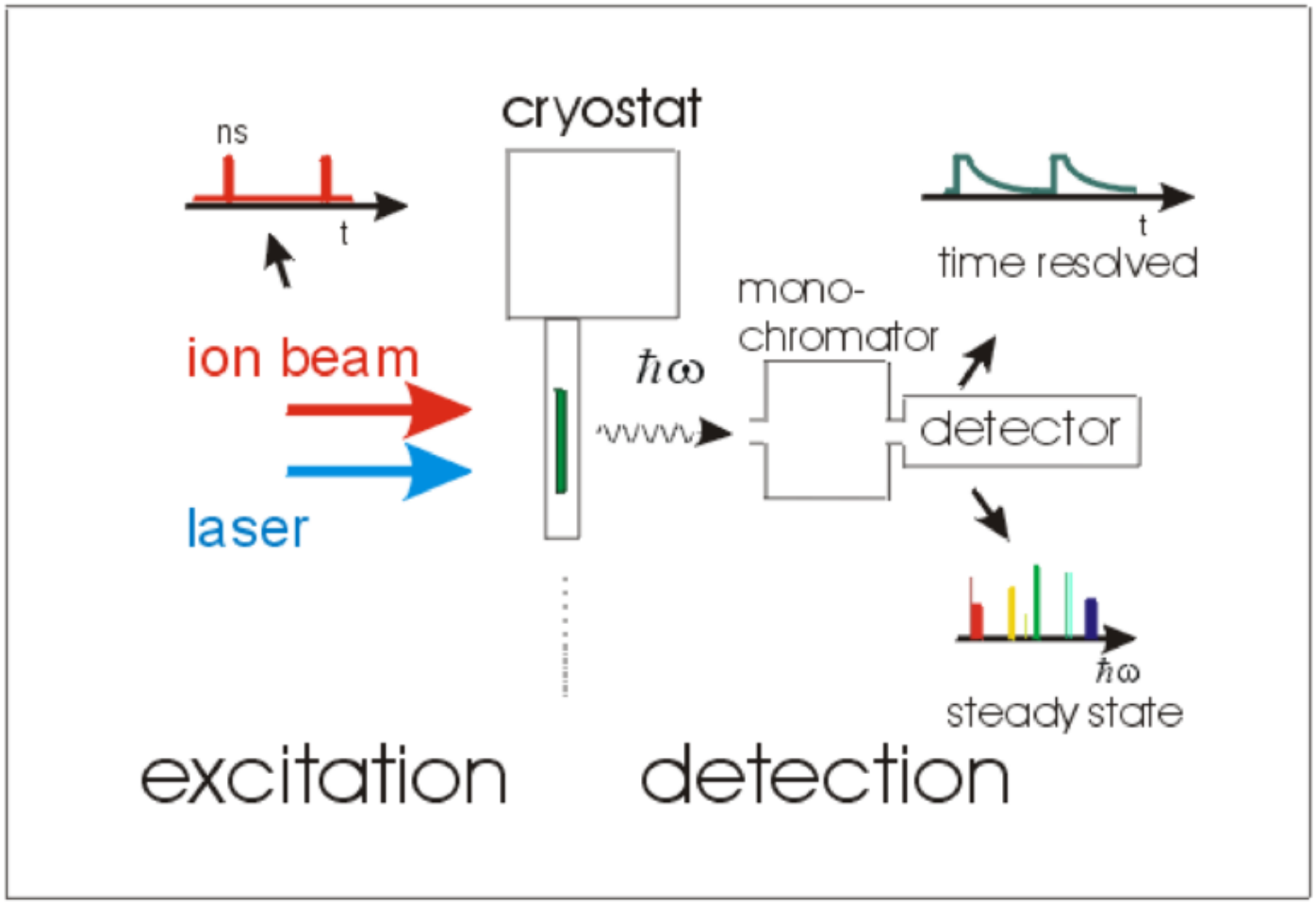
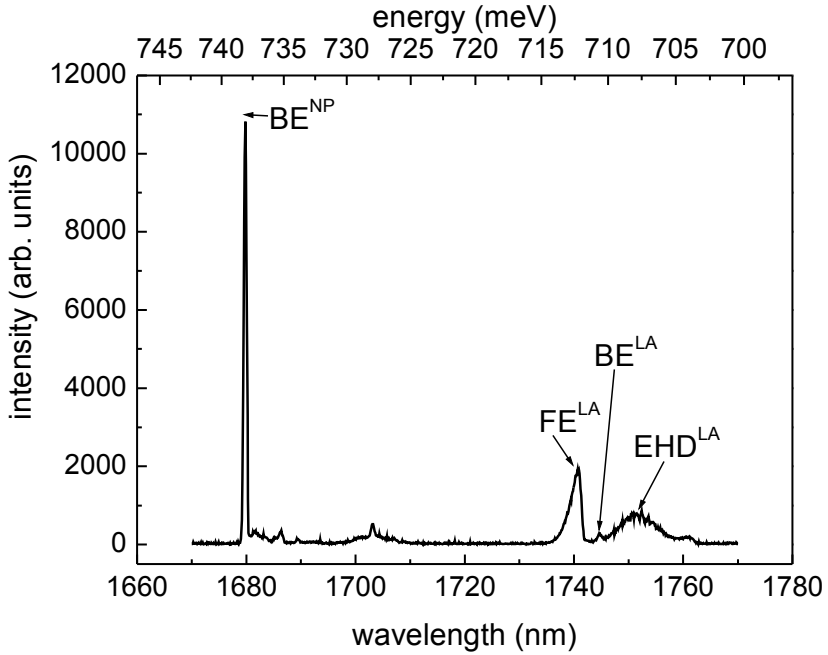
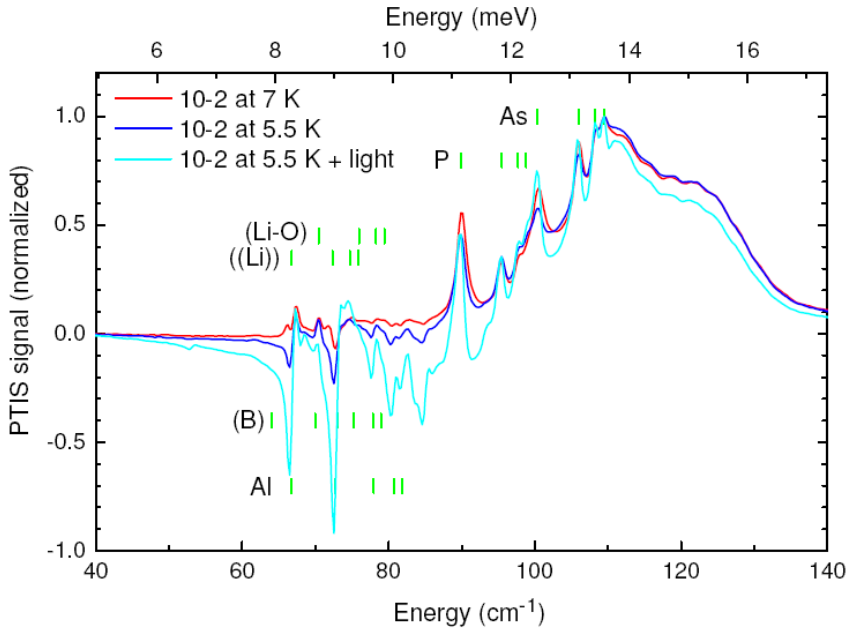
Photoluminescence

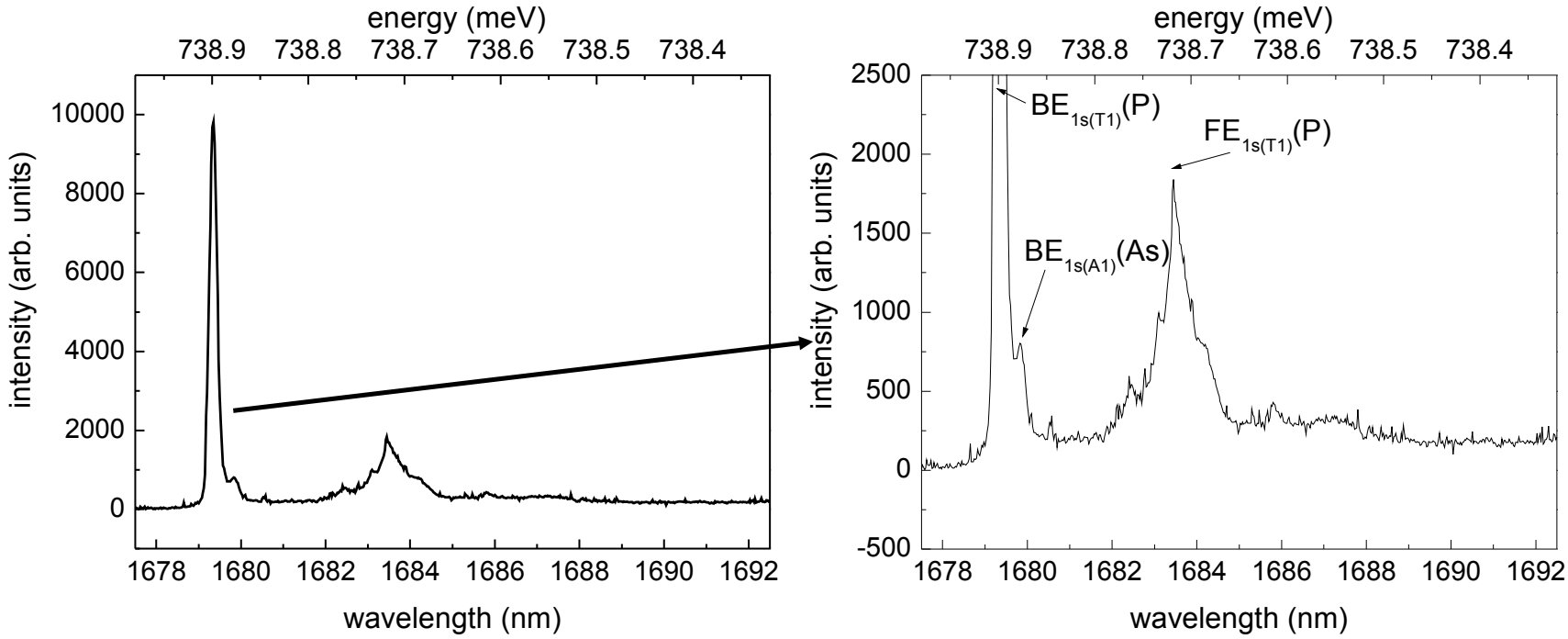


PL vs. PTIS


energy (meV)
745 740 735 730 725 720 715 710 705 700
12000
10000
8000
6000
4000
2000
0
intensity (arb. units)
BE^NP
BE^LA
FE^LA
EHD^LA
1660 1680 1700 1720 1740 1760 1780
wavelength (nm)

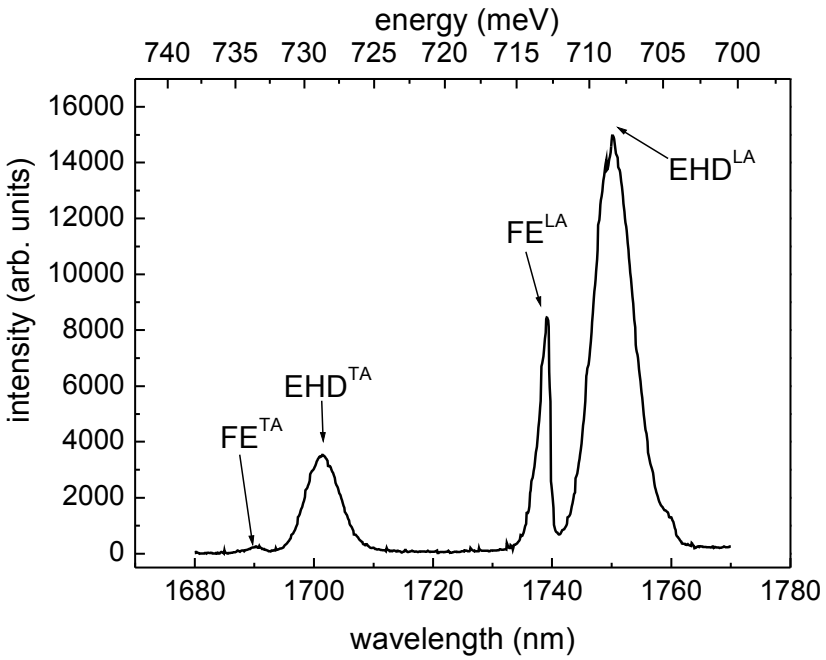

Energy (meV)
6 8 10 12 14 16
10-2 at 7 K
10-2 at 5.5 K
10-2 at 5.5 K + light
As
P
(Li-O)
((Li))
(B)
Al
1.0
0.5
0.0
-0.5
-1.0
PTIS signal (normalized)
40 60 80 100 120 140
Energy (cm^-1)

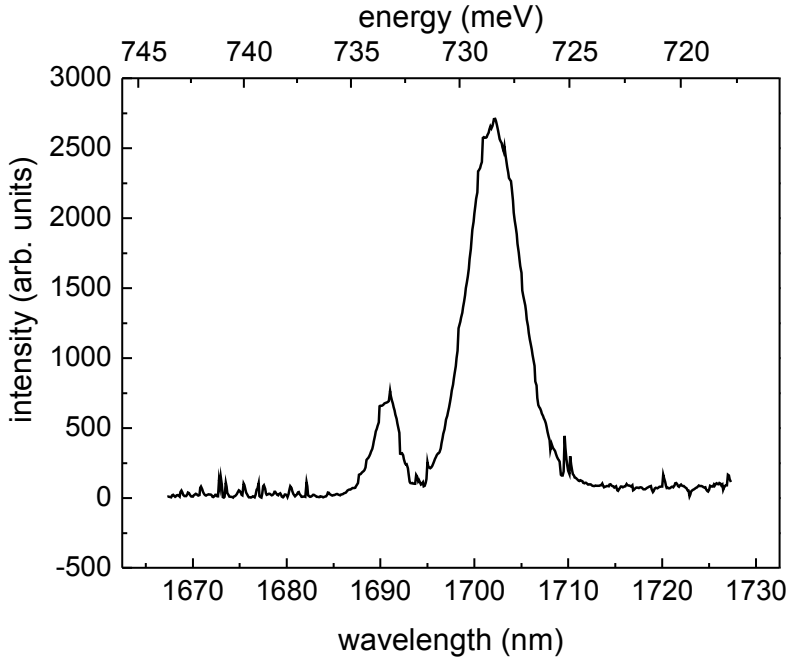
Sample Ge#4-7/3



→ Phosphorous exciton much stronger than arsenic exciton (ratio 10:1)

Ge81132-1 (Canberra material)





→No bound excitons visible → low impurity concentrations

→ very pure material

Crystal pulling - near future - conclusion

- Many crystals pulled and analyzed
- The source of impurities identified: is the Czochralski puller itself
- IKZ will upgrade the Cz. puller. First results in 4-6 weeks
- New analytical method from TU Dresden
- More detailed analysis of the existing crystals being done
- We are planing to make a small detector from the float-zone crystal
- The goal of having detector grade crystals in early 2009 is unlikely but still within reach