Study of the Activated GaAs Surface for Application as an Electron Source in Particle Accelerators

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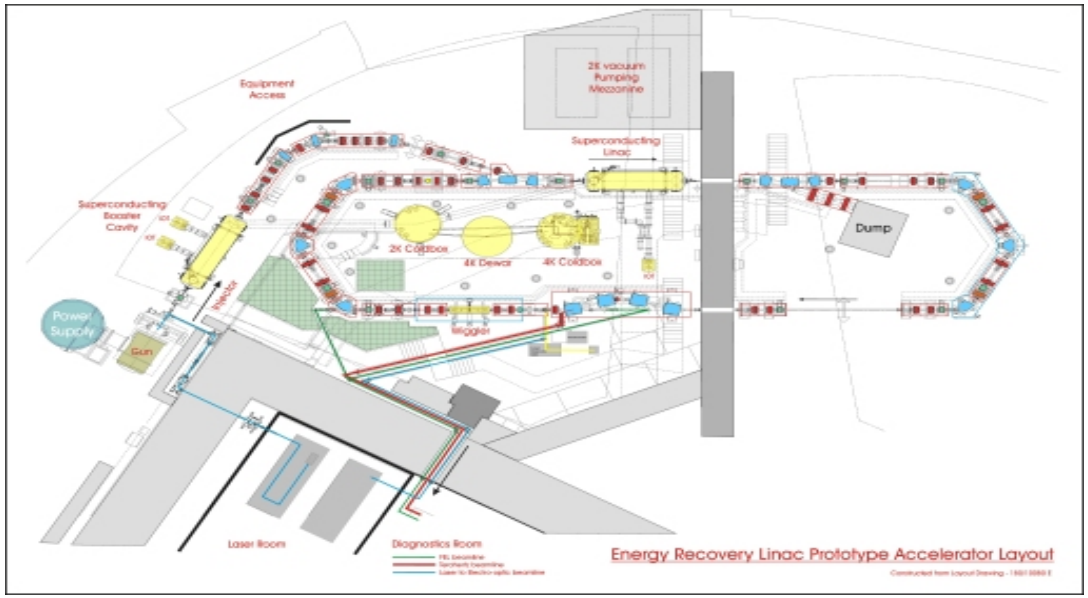
Outline

- Introduction
- Experimental setup
- Preliminary results
- Summary

Introduction

- The Accelerators and Lasers in Combined Experimental (ALICE) is a 35 *Me*V energy recovery test facility currently under construction at Daresbury Laboratory

Alice
Accelerators and Lasers
In Combined Experiments



Photocathode for ALICE

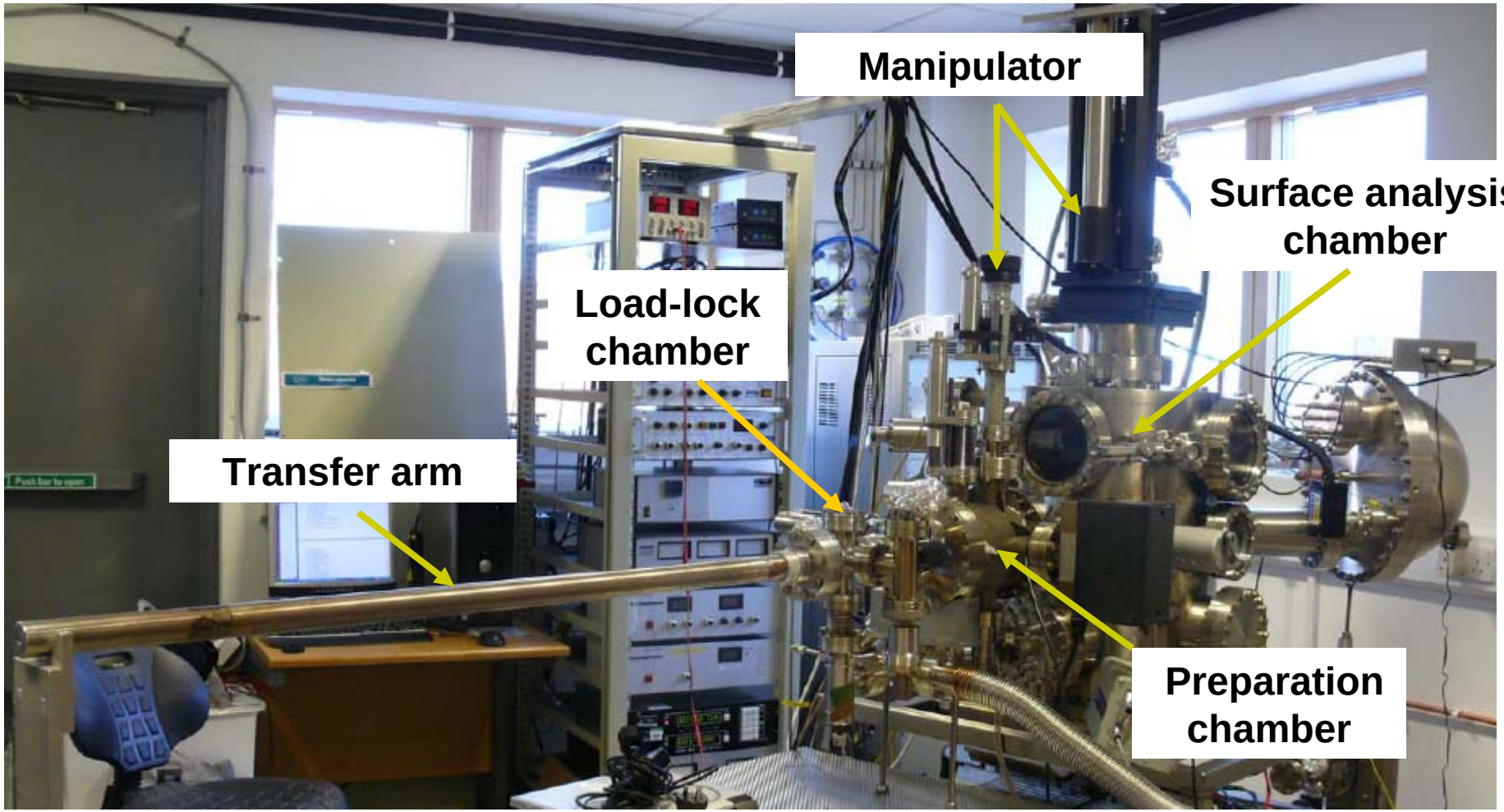
- The type III-V semiconductor, especially GaAs, photocathode has been focused.
- This type of photocathode has high quantum efficiency and generates high polarised electron.
- However, it need to be activated to the negative electron affinity (NEA) state.
- This photocathode need to be kept in the extreme high vacuum (XHV) conditions.

Photocathode R&D at Daresbury Laboratory

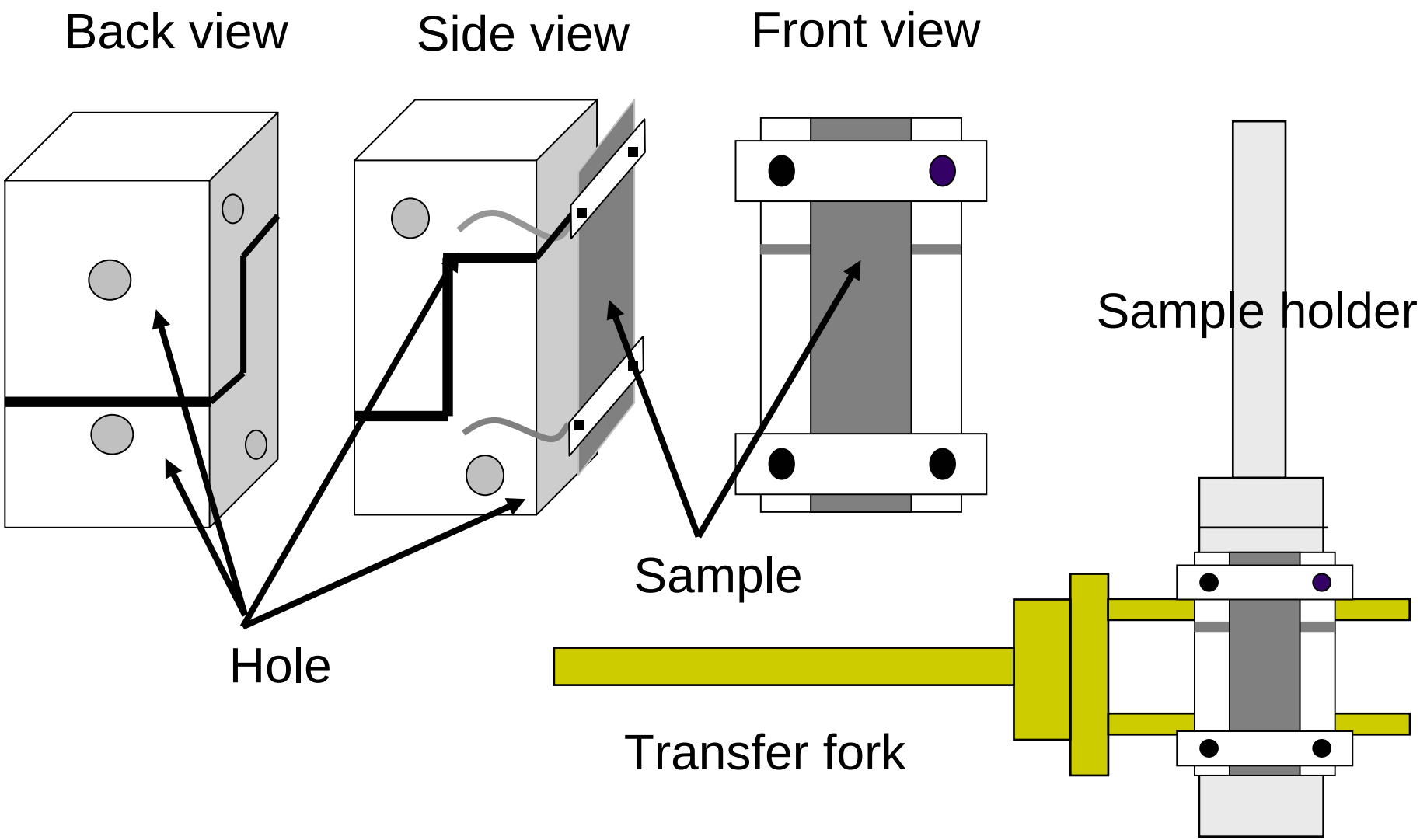
- Study a range of photocathode material in detail, investigating and developing the various fundamental processes, such as preparation process to maximise their performance.

- The initial focus will be on GaAs, but alternative materials such as Cs_2Te and InGaP will be also studied.

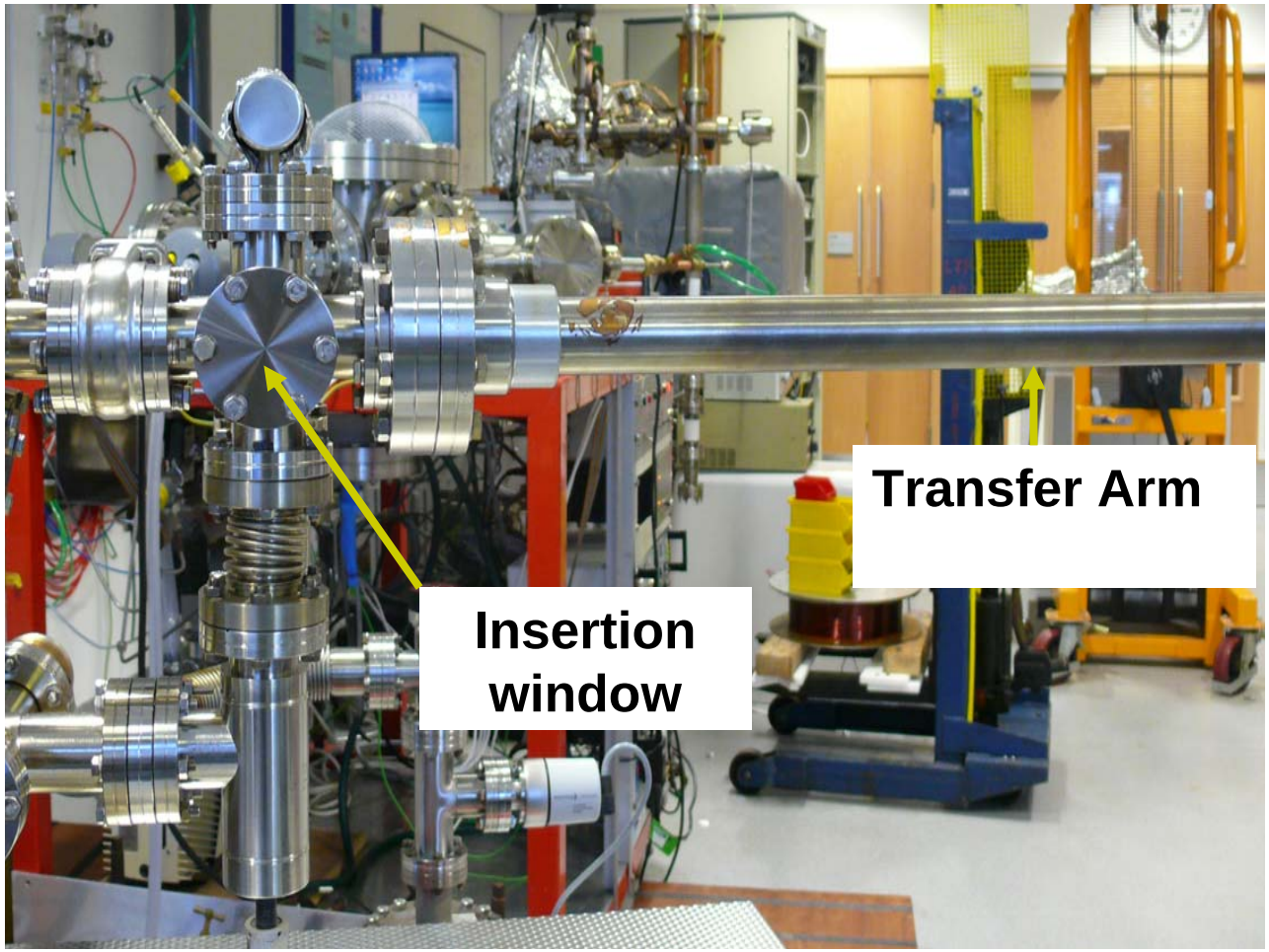
Experimental Setup



Sample mounted



Load-lock Chamber



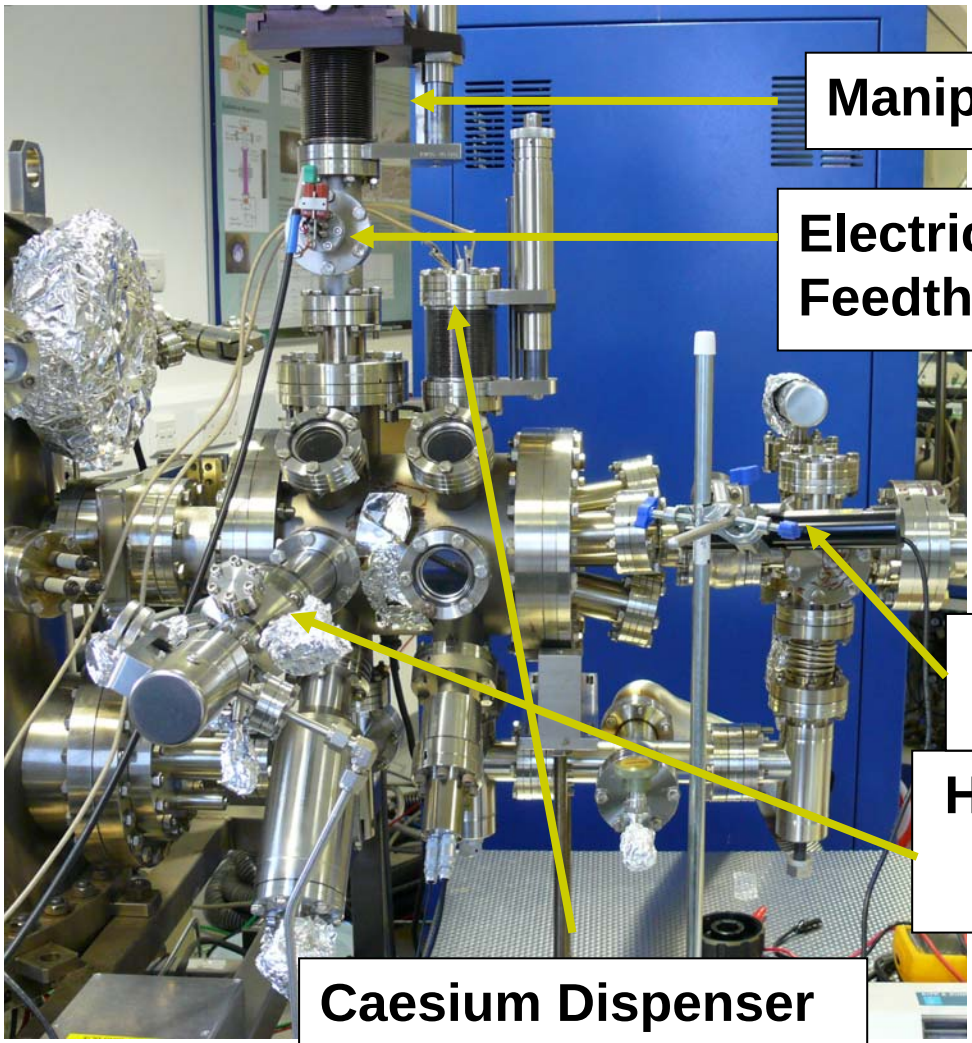
Preparation Process

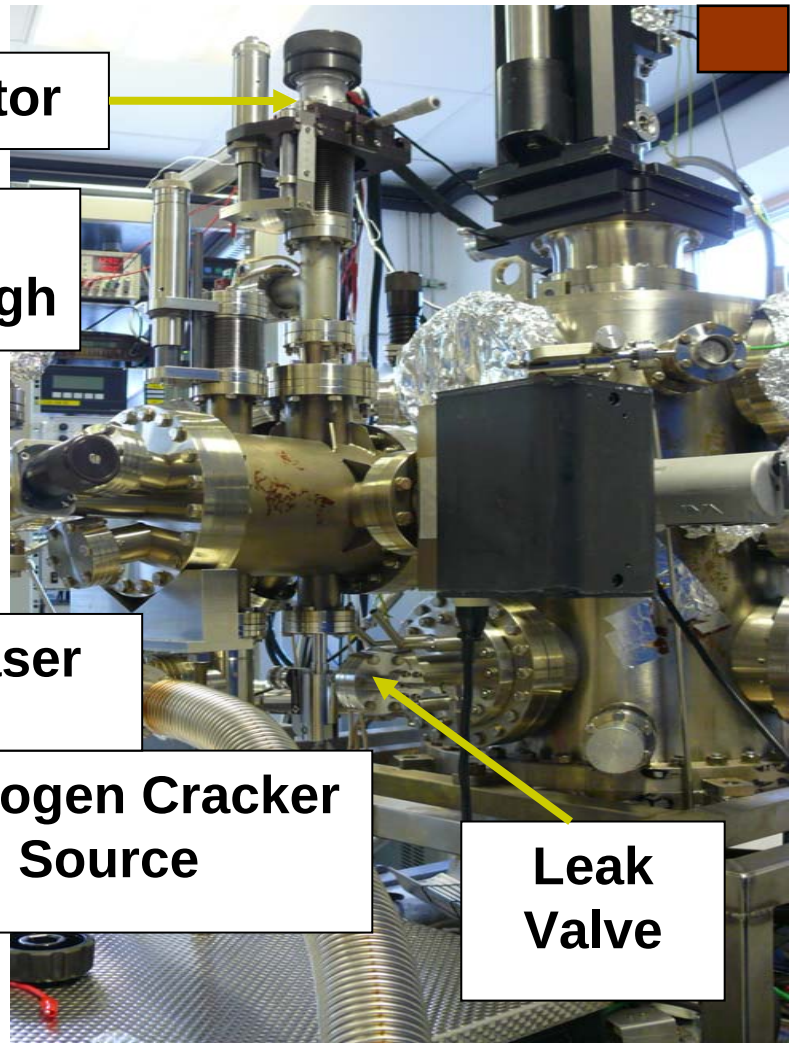
- The GaAs sample need to be cleaned before activated to the NEA state.
- Choices of cleaning process

  - Heat in the vacuum

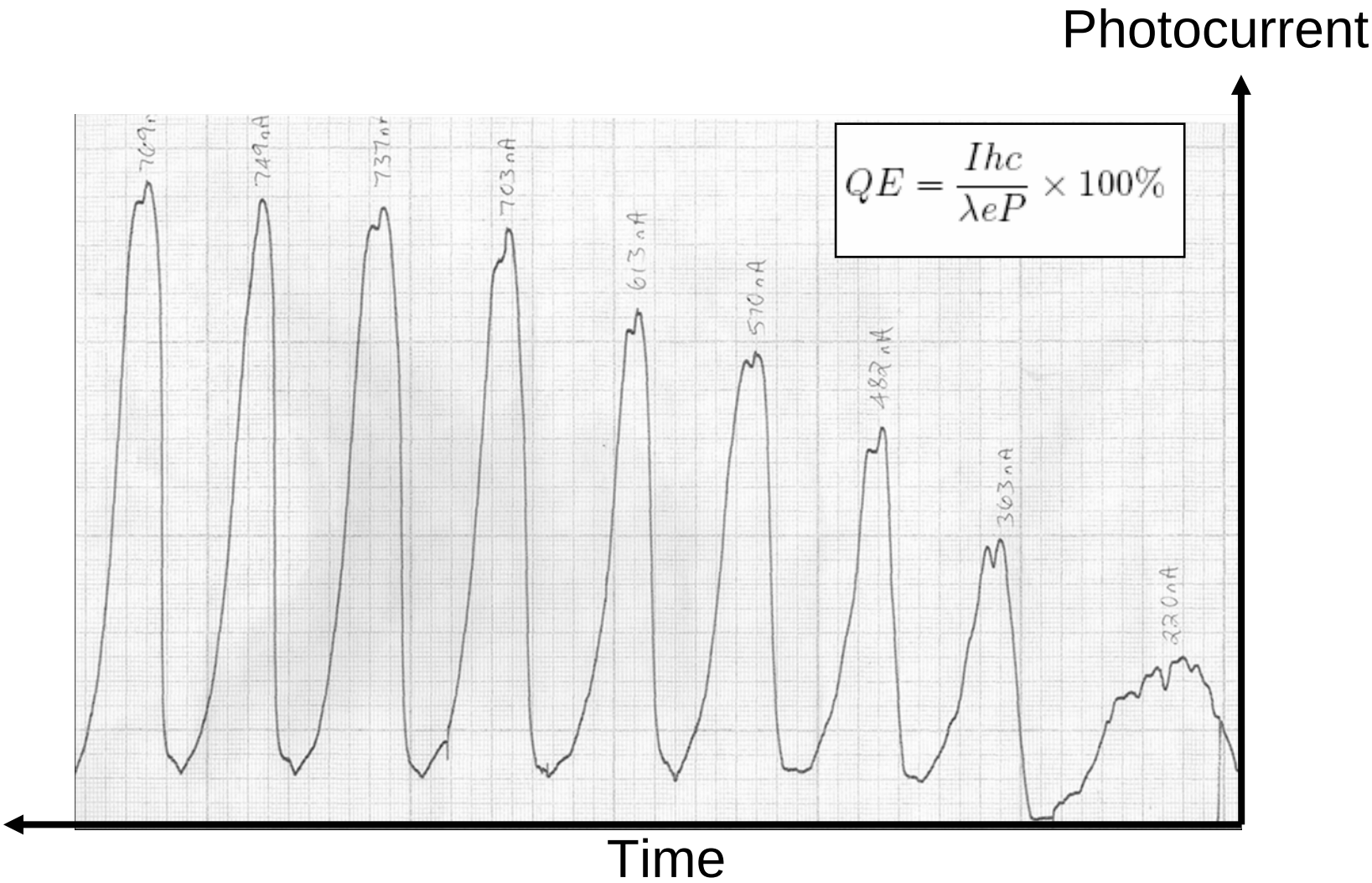
  - Atomic hydrogen cleaning
- Activated to the NEA state by applying caesium and oxidant (either O_2 or NF_3) onto its clean crystal surface.
- The standard Yo-Yo method is employed at room temperature.

Preparation Chamber

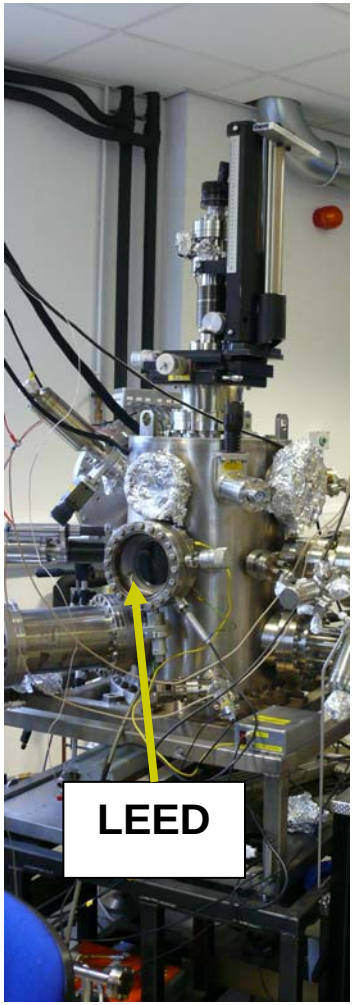


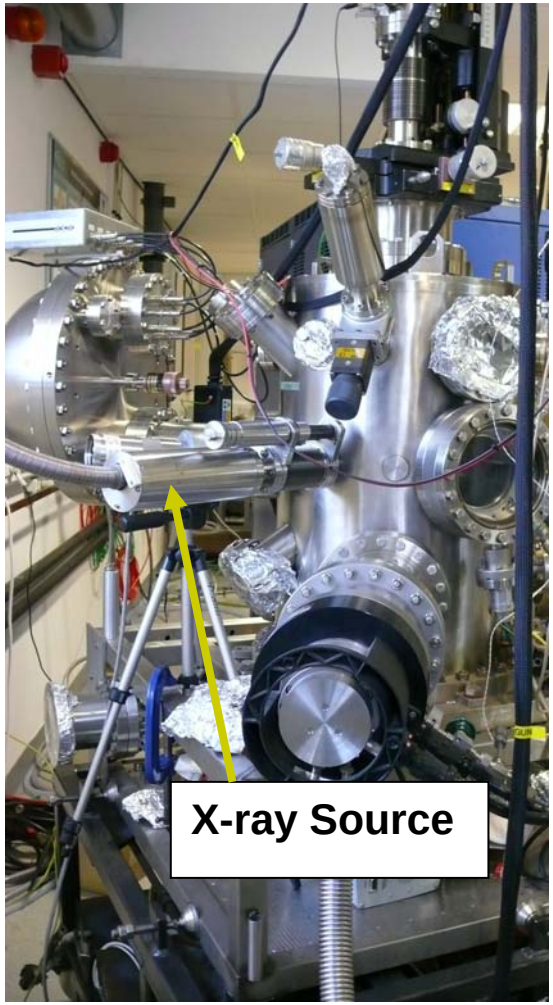


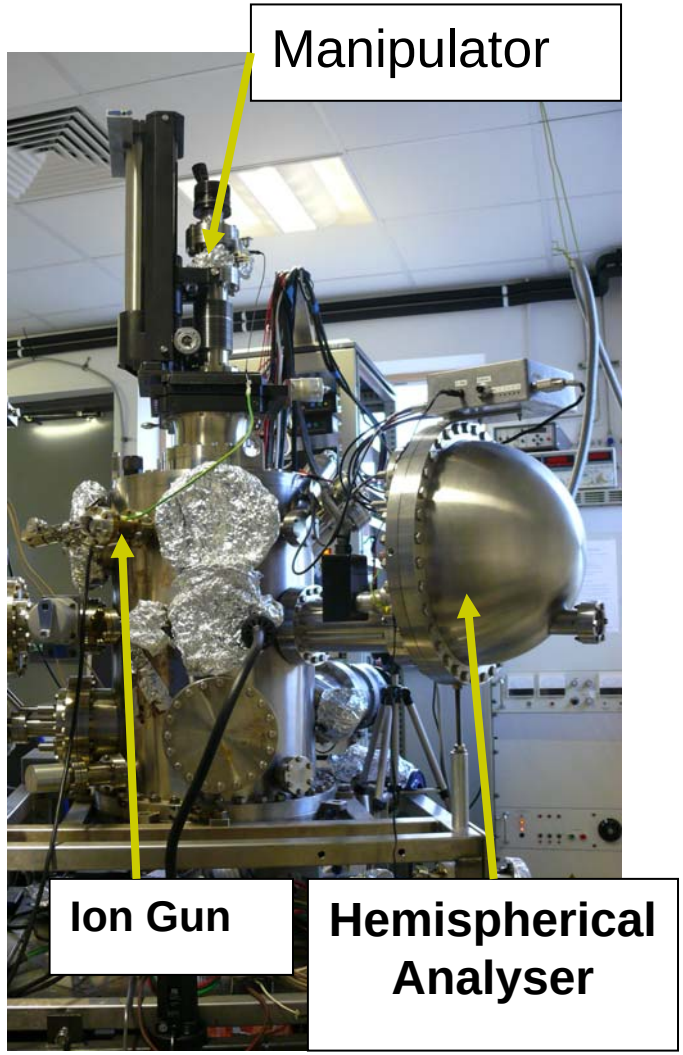
The Yo-Yo method



Surface Analysis Chamber

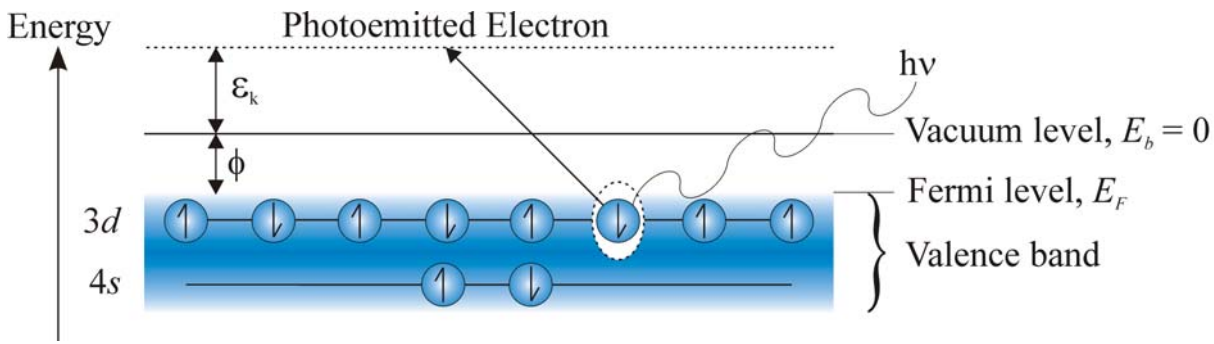




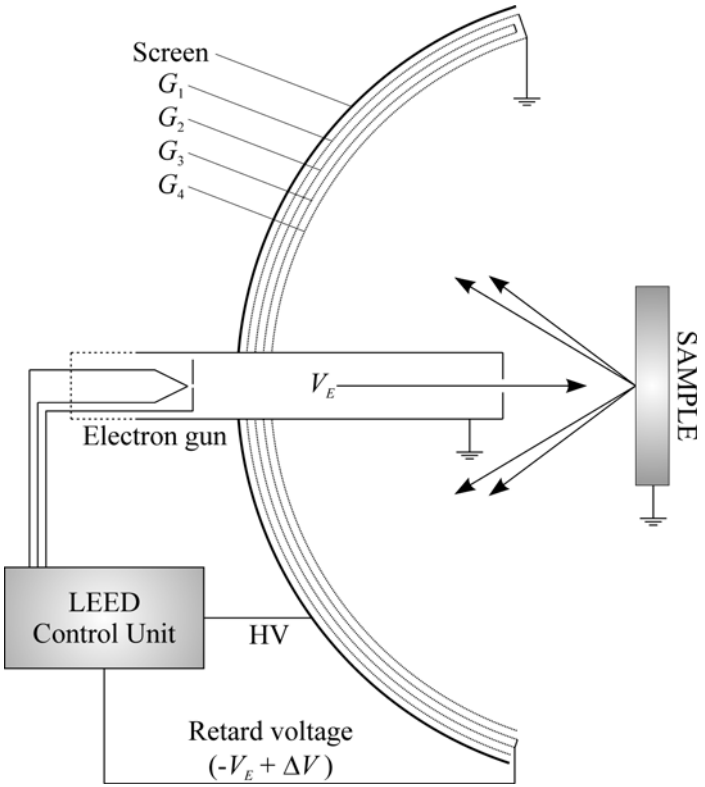


X-ray Photoelectron Spectroscopy (XPS) Technique

- Used to investigate the chemical composition of a material surface.
- Irradiates a material surface with soft x-rays, *Mg Kα* or *Al Kα* in a UHV.
- Cause the electrons to be emitted by the photoelectric effect.
- The chemical composition of a material is identified by analysing the kinetic energy and the number of emitted electrons.



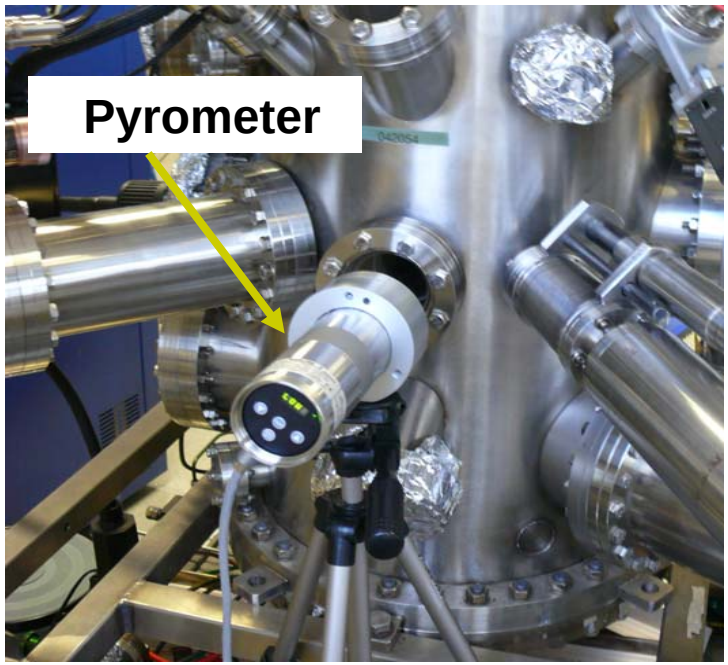
Low Energy Electron Diffraction (LEED) Technique

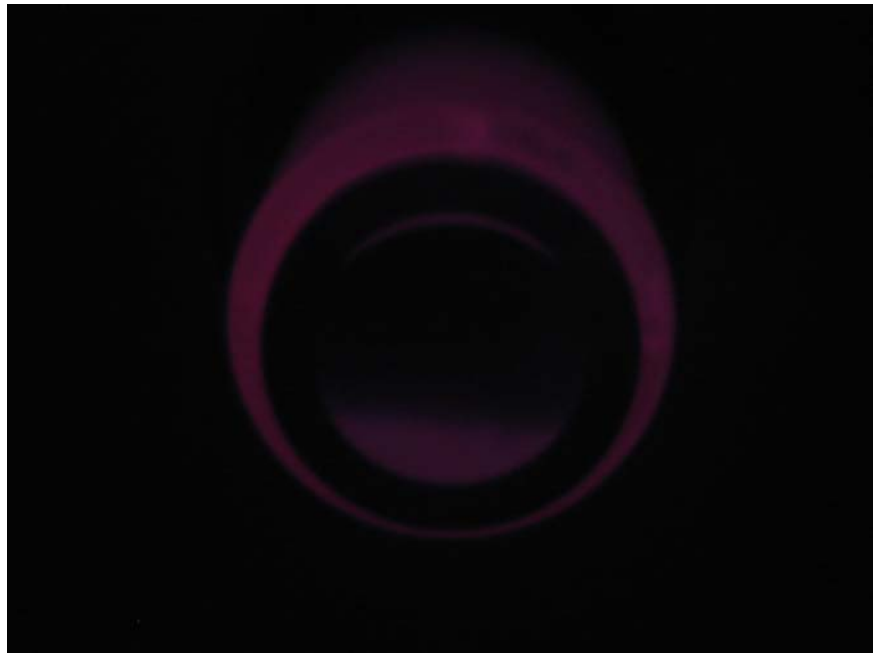


- Used to determine the surface structures of a material
- Incidents a beam of low energy electrons into the sample surface
- The electron beam will be diffracted following the Bragg condition.
- Determine the surface structure from the intensity and diffraction pattern of the back-scattered electrons

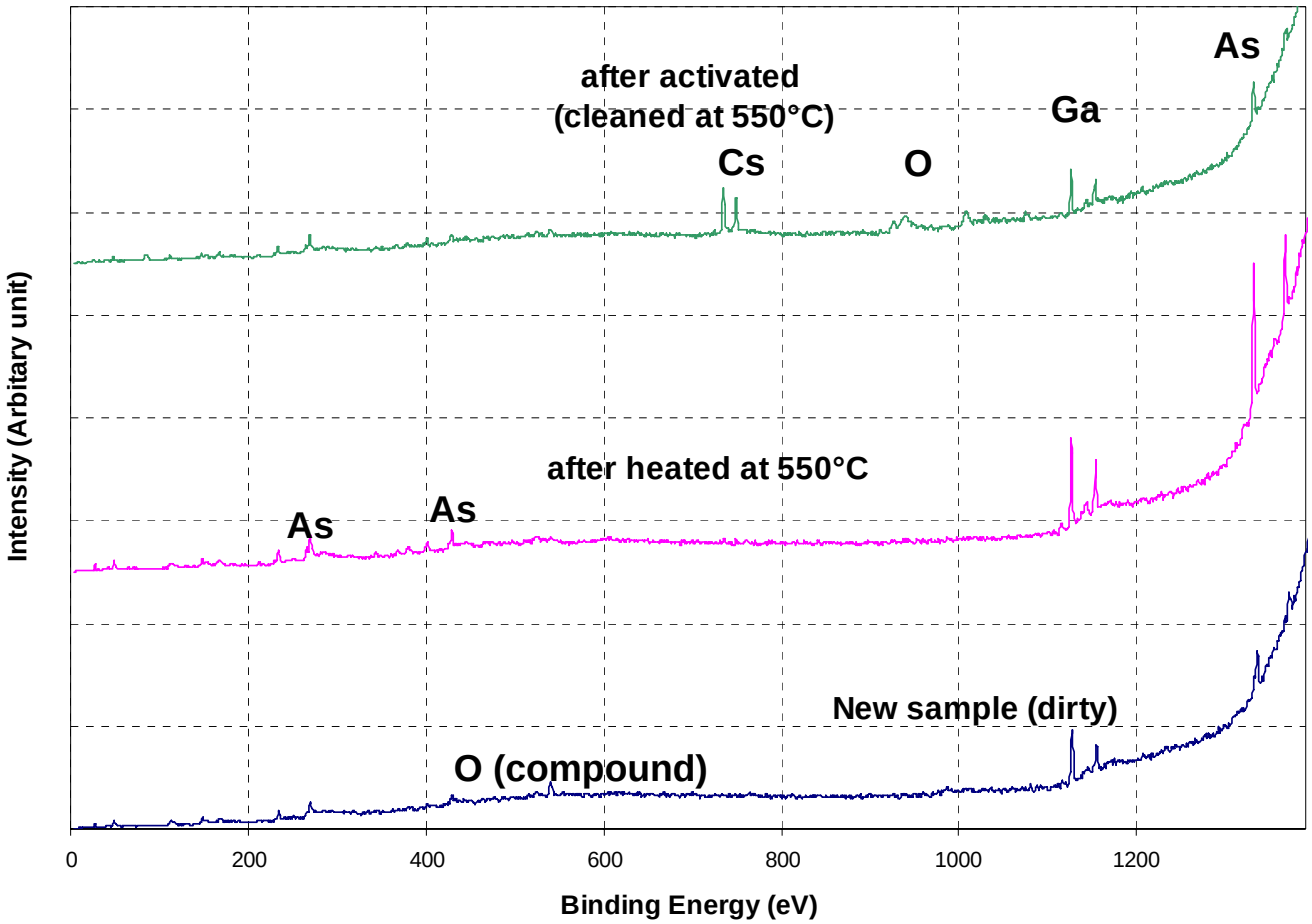
Effect of the temperature in heat cleaning

- Heat for 1 hour in the UHV
- Observe the temperature by using the pyrometer

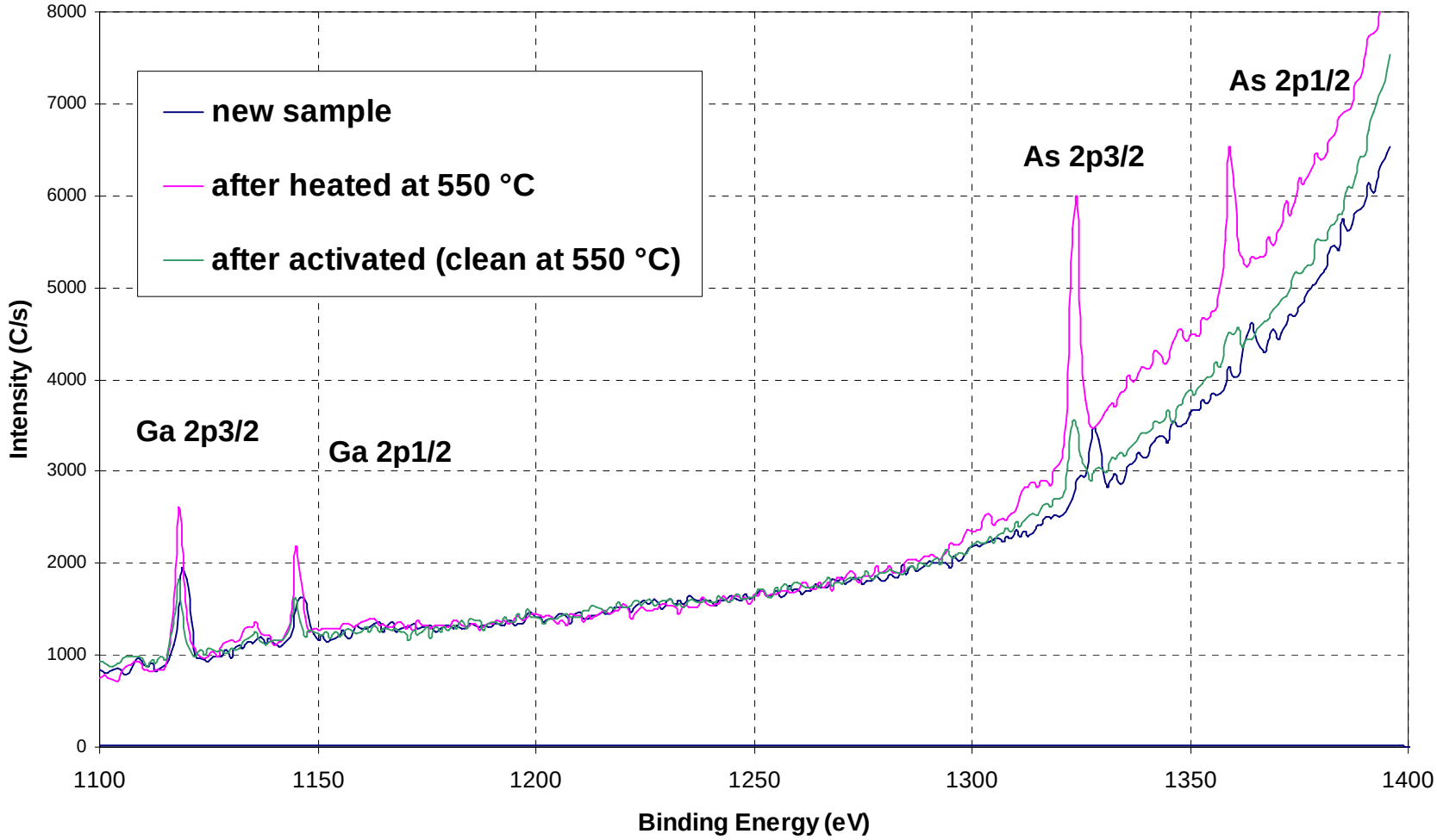




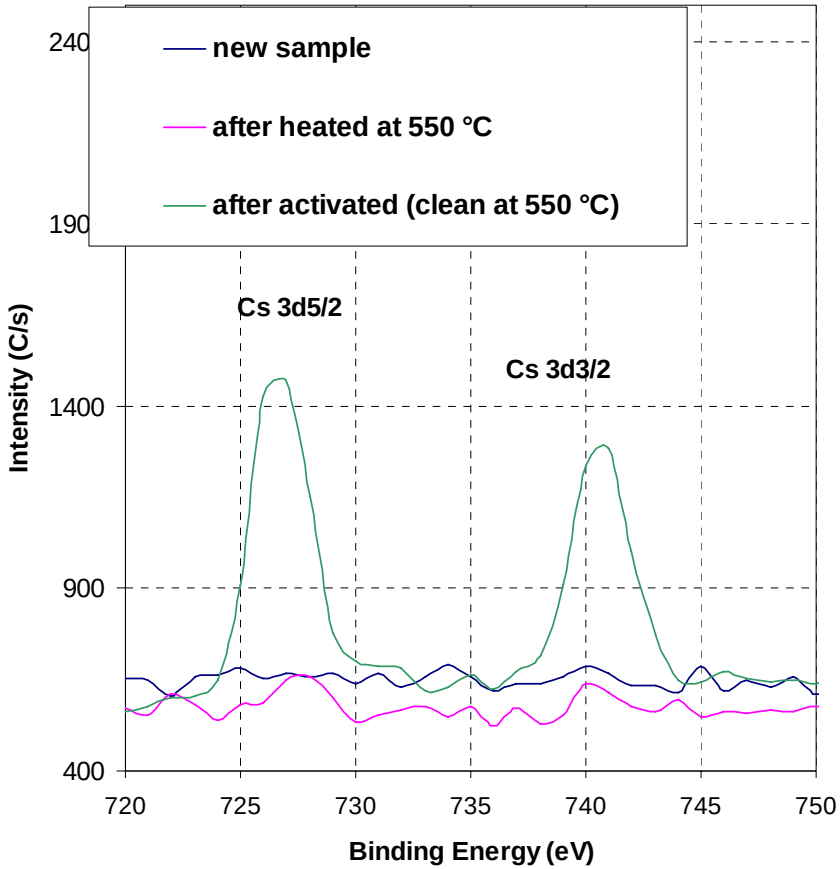
XPS results

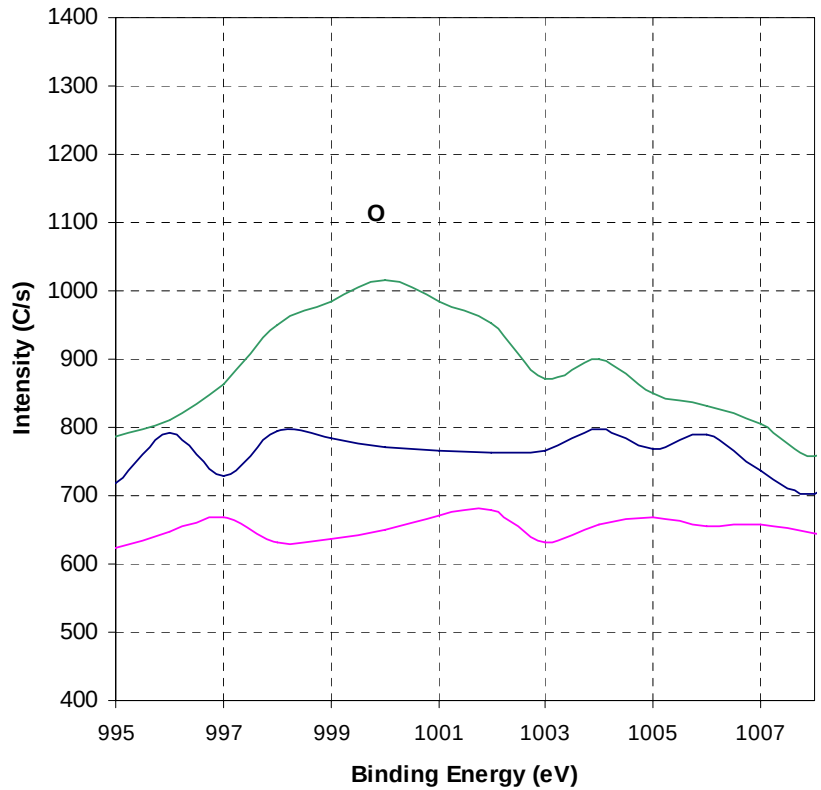

after activated
(cleaned at 550°C)
Cs
O
Ga
As
after heated at 550°C
As
As
New sample (dirty)
O (compound)
Intensity (Arbitary unit)
0
200
400
600
800
1000
1200
Binding Energy (eV)

XPS results

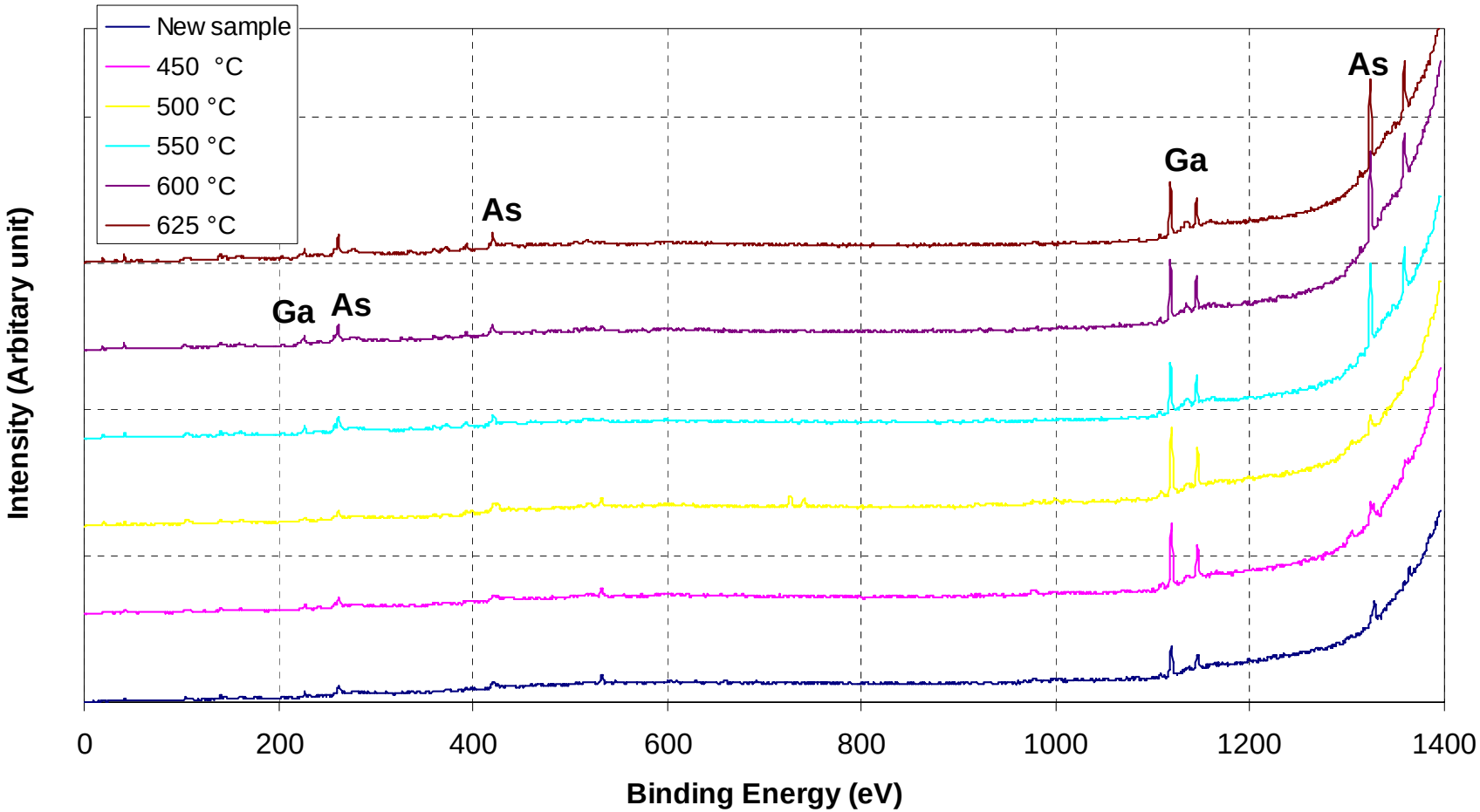

new sample
after heated at 550 °C
after activated (clean at 550 °C)
Ga 2p3/2
Ga 2p1/2
As 2p3/2
As 2p1/2
Intensity (C/s)
Binding Energy (eV)
0
1000
2000
3000
4000
5000
6000
7000
8000
1100
1150
1200
1250
1300
1350
1400

XPS results

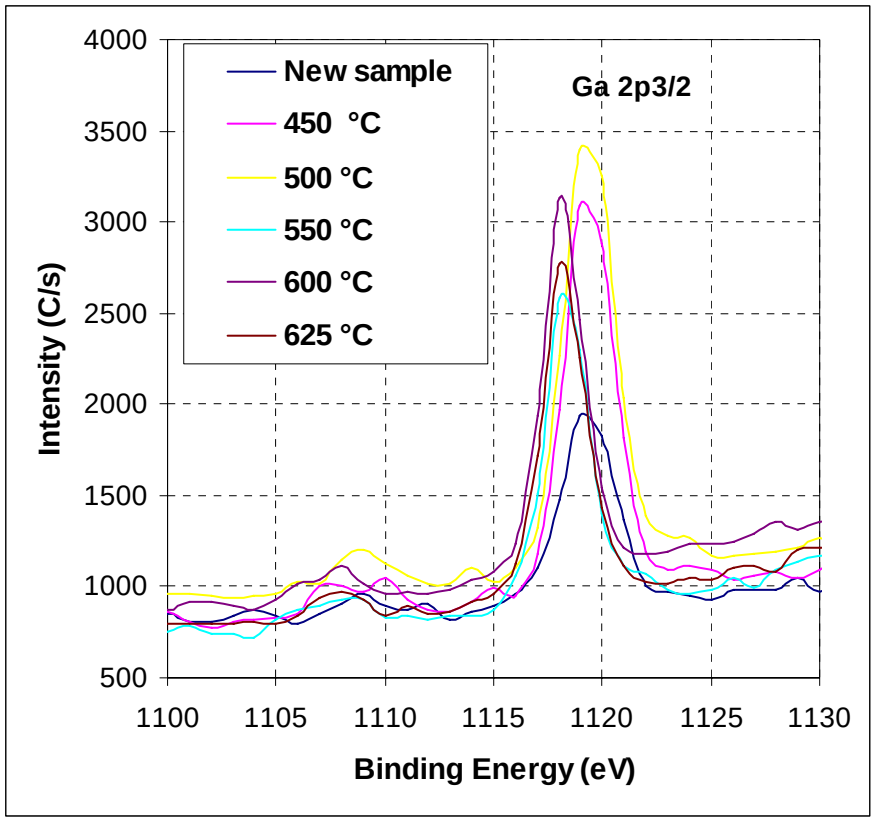

new sample
after heated at 550 °C
after activated (clean at 550 °C)
Cs 3d5/2
Cs 3d3/2
Intensity (C/s)
Binding Energy (eV)
240
190
1400
900
400
720
725
730
735
740
745
750

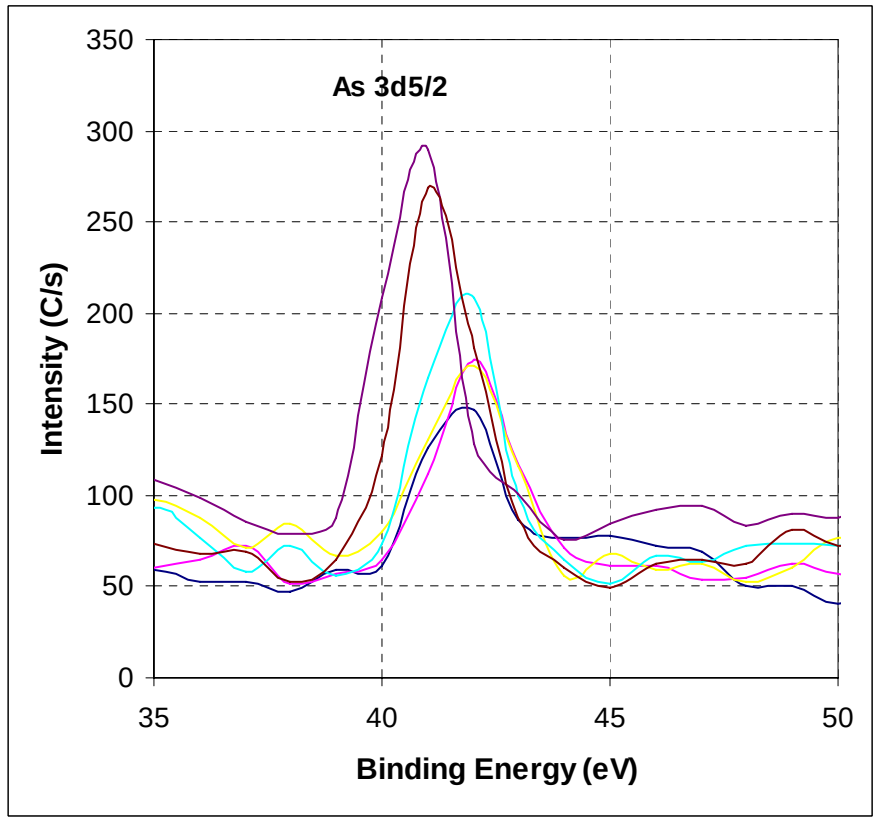

O
Intensity (C/s)
Binding Energy (eV)
1400
1300
1200
1100
1000
900
800
700
600
500
400
995
997
999
1001
1003
1005
1007

Heat Cleaning

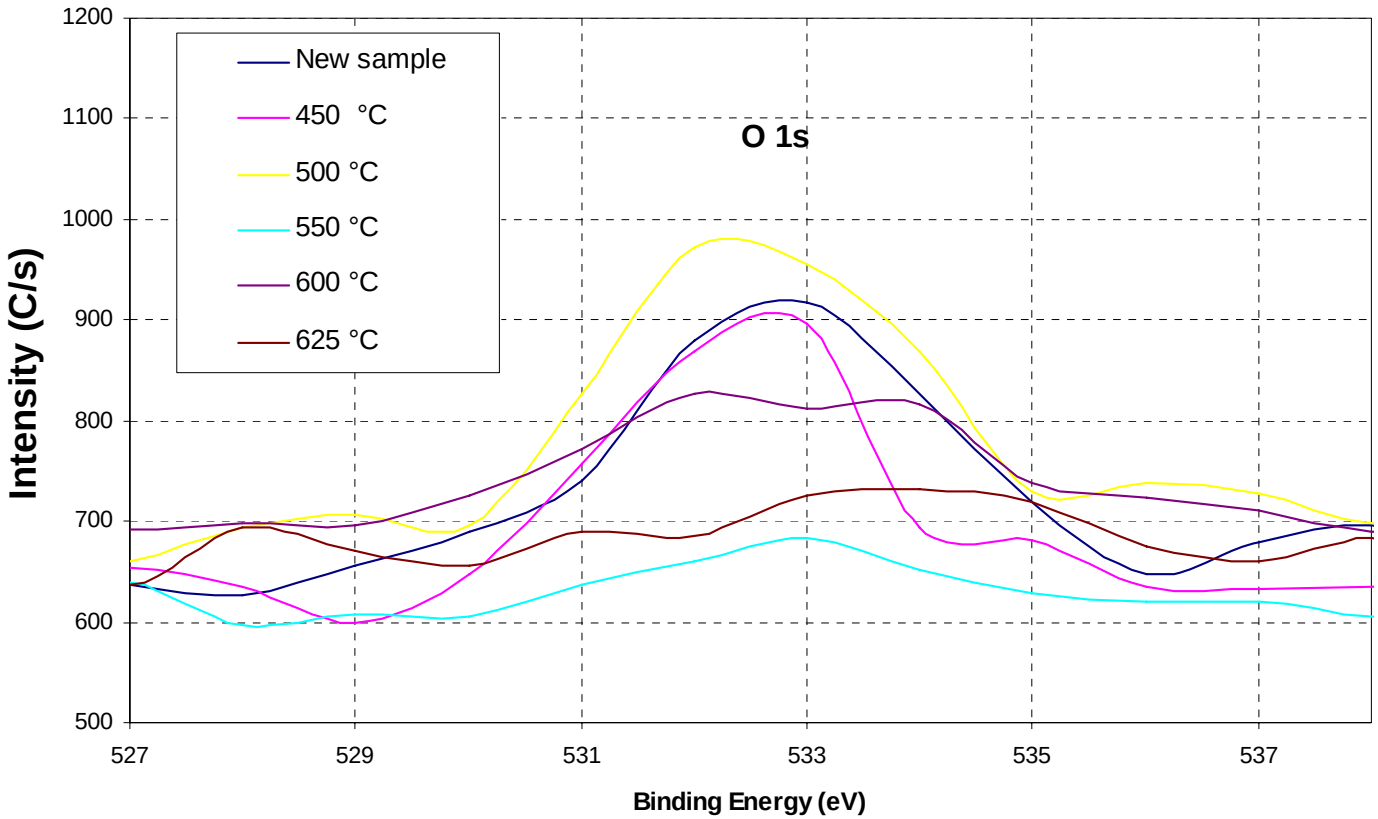


Heat Cleaning



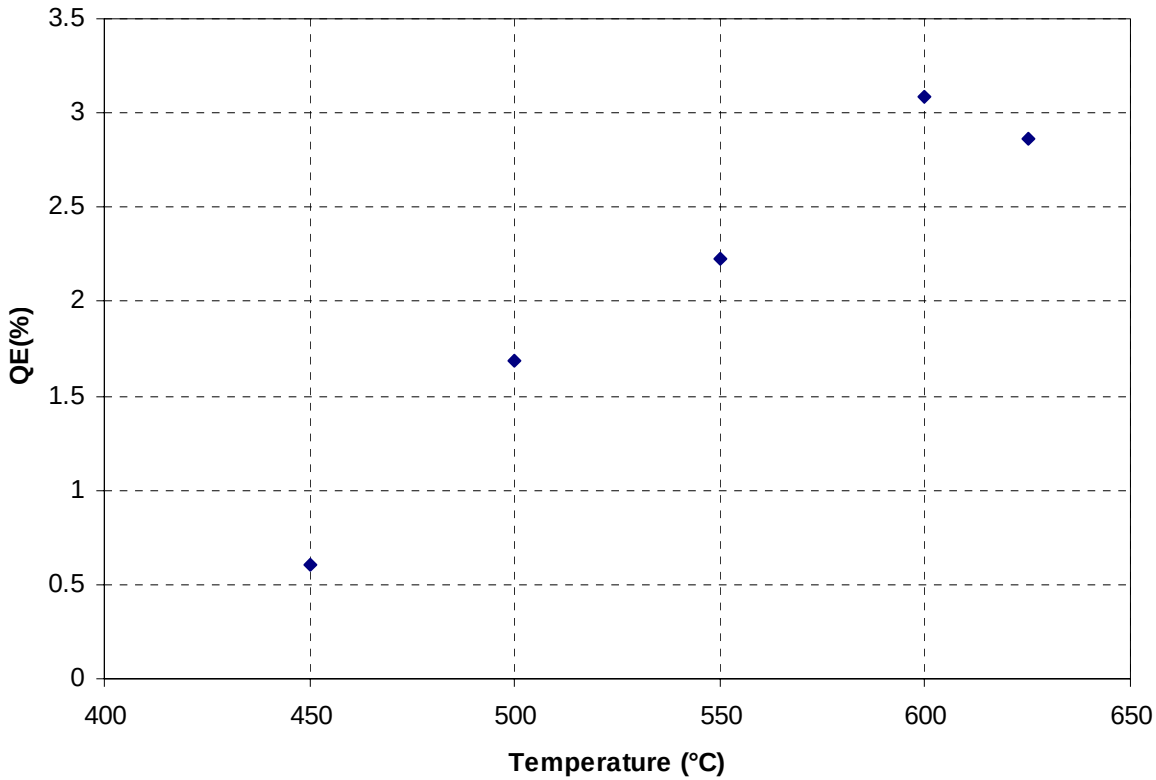


Heat Cleaning



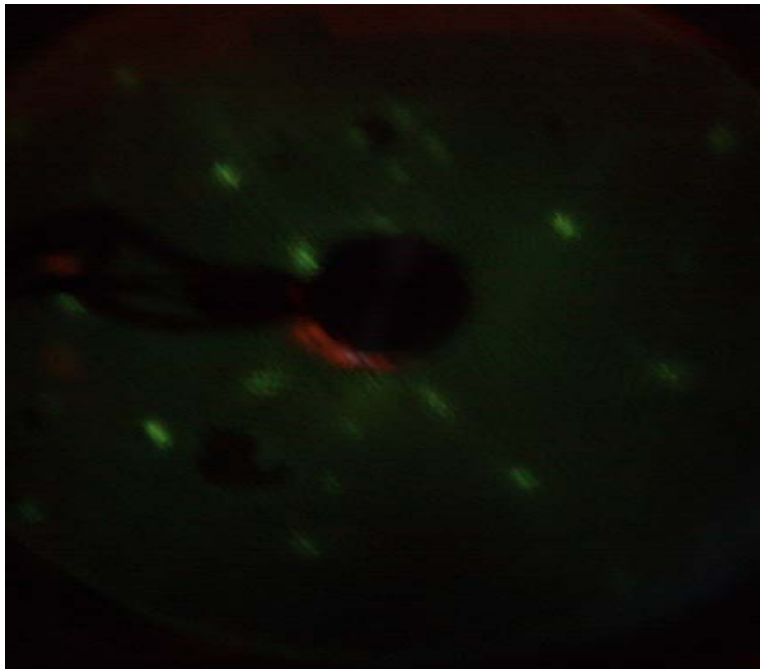
Quantum efficiency (QE)

The effect of the heat temperature on the QE of the GaAs photocathode



LEED Pattern

- Picture of LEED diffraction of the GaAs after heated at 600 C for 1 hour



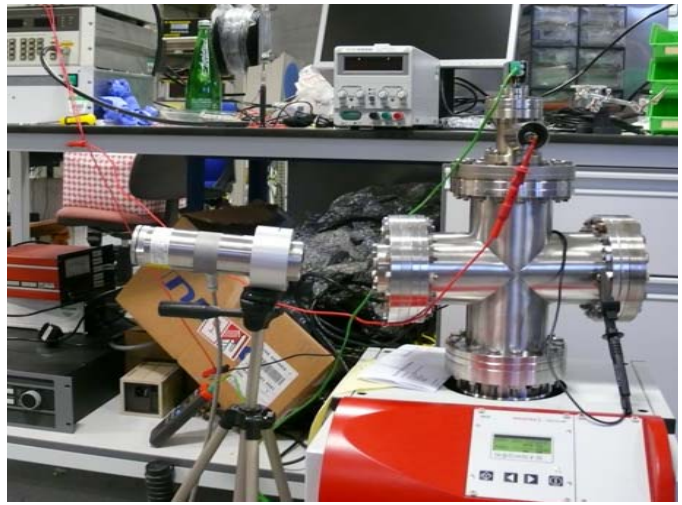
Summary

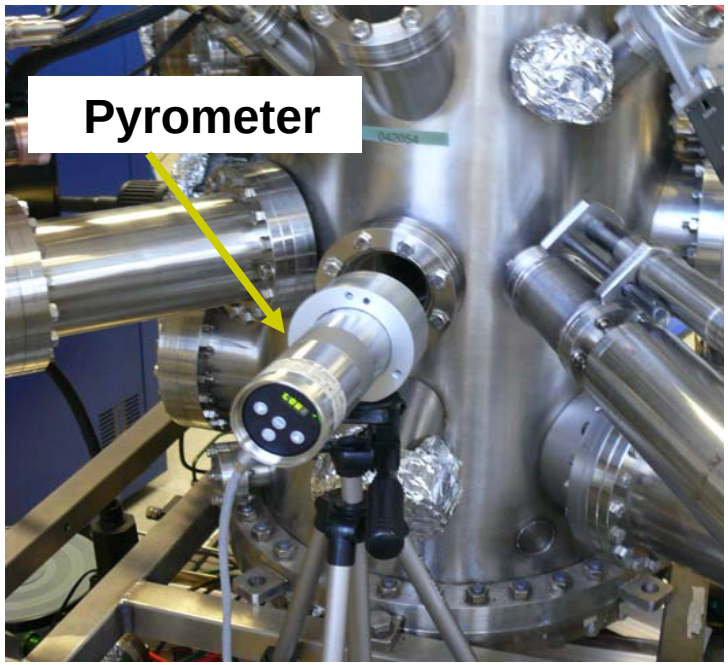
- The vacuum system which supports the surface science techniques have been setup to study the activation process of the NEA GaAs photocathode.
- The effect of the temperature in heat cleaning process is studied by using the XPS and LEED.
- We have presently just finished the installation and the testing of components in our test chamber. For the future works, the atomic hydrogen cleaning and lifetime will be studied.

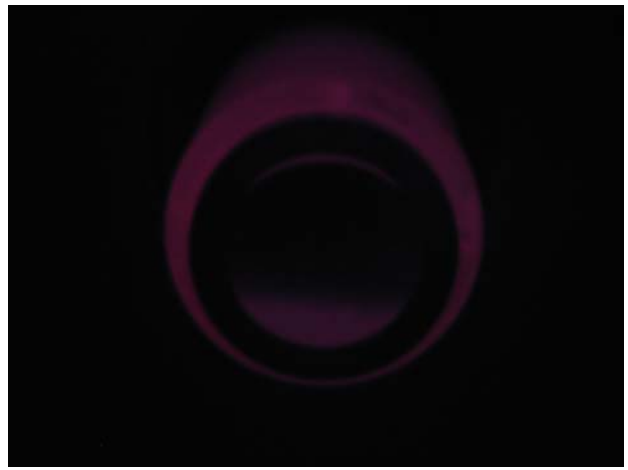
- Thank you for your attention

Effect of the temperature in heat cleaning

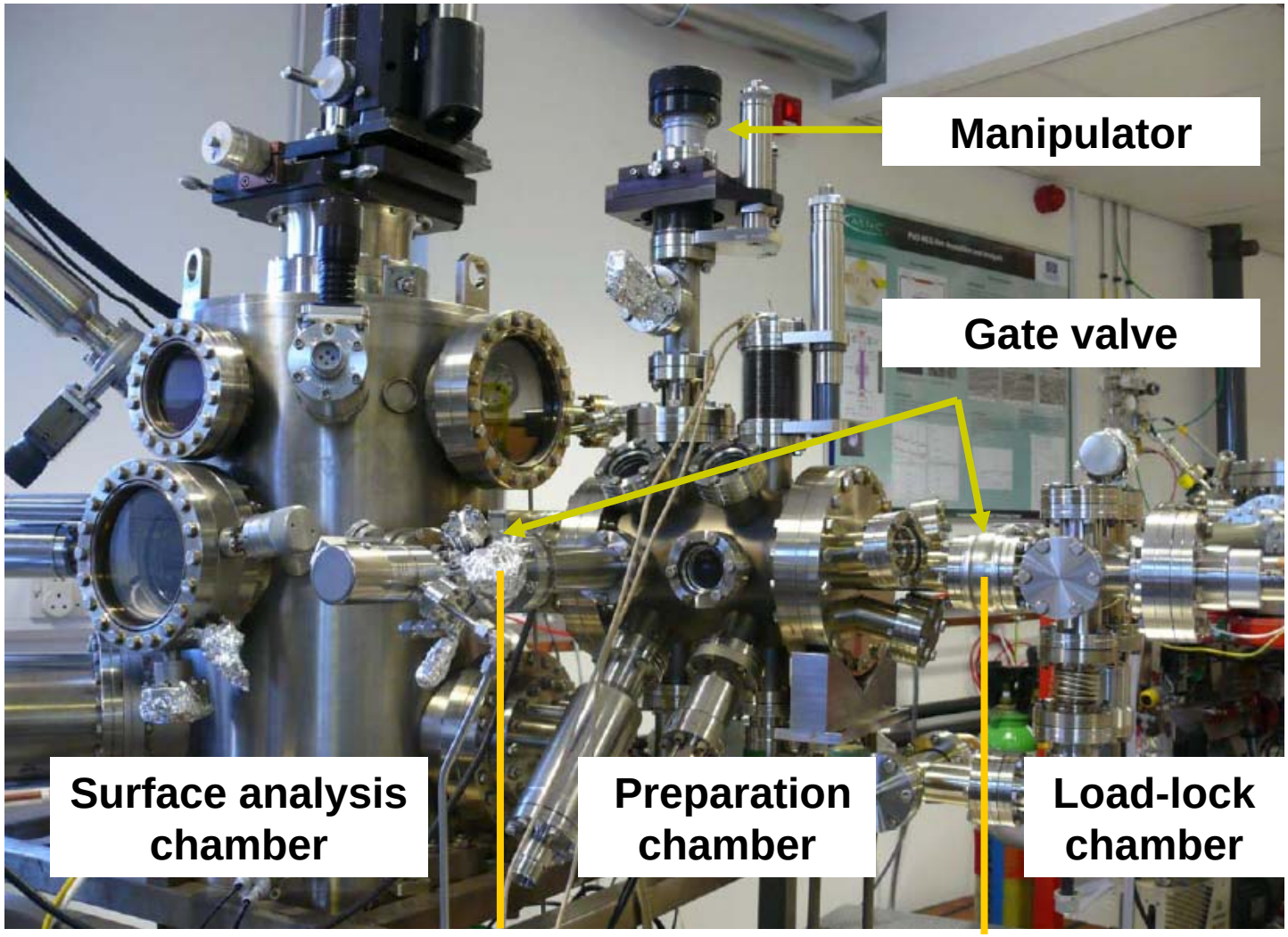
- Heat for 1 hour in the UHV
- Observe the temperature by using the pyrometer





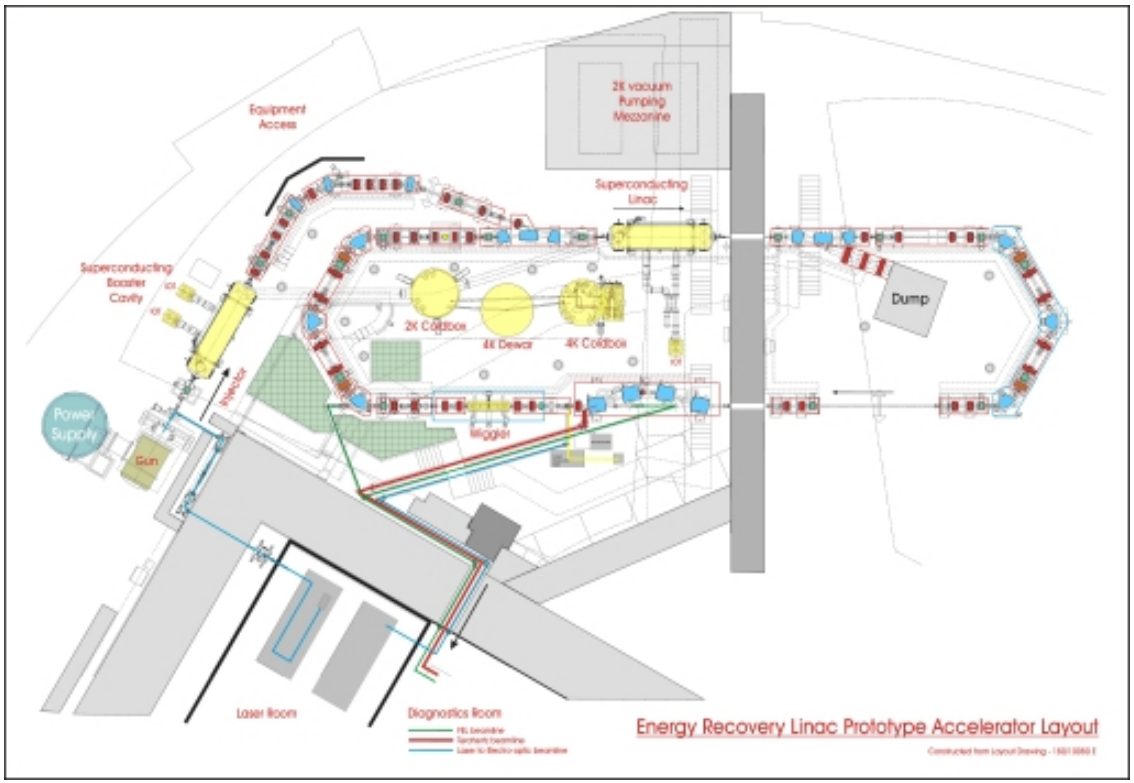


Experimental Setup



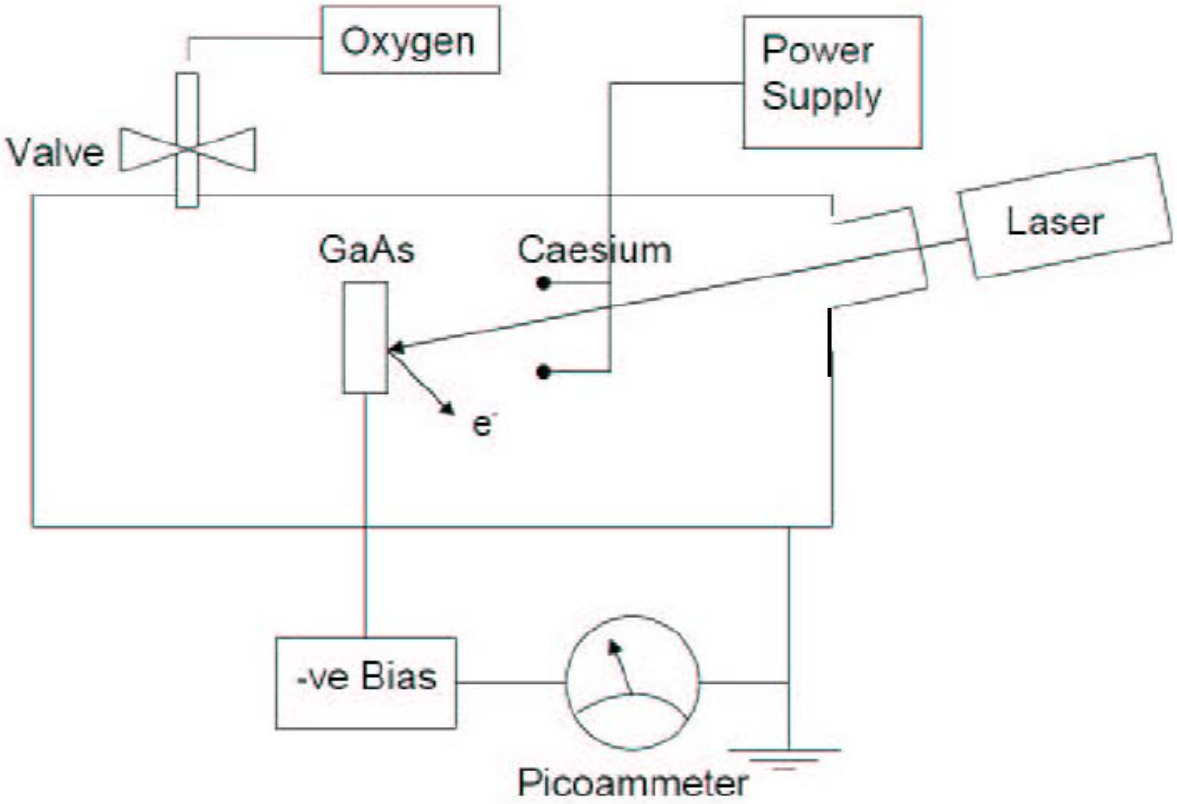
Introduction

- The Accelerators and Lasers in Combined Experimental (ALICE) is a 35 *Me*V energy recovery test facility currently under construction at Daresbury Laboratory



- The photoinjector is based on the JLab FEL DC photocathode gun.
- A CW current of 6.5 *m*A as a pre-cursor to the 100 *m*A
- Normalised emittance of < 1 π *mm mrad*.

Diagram of the activation process



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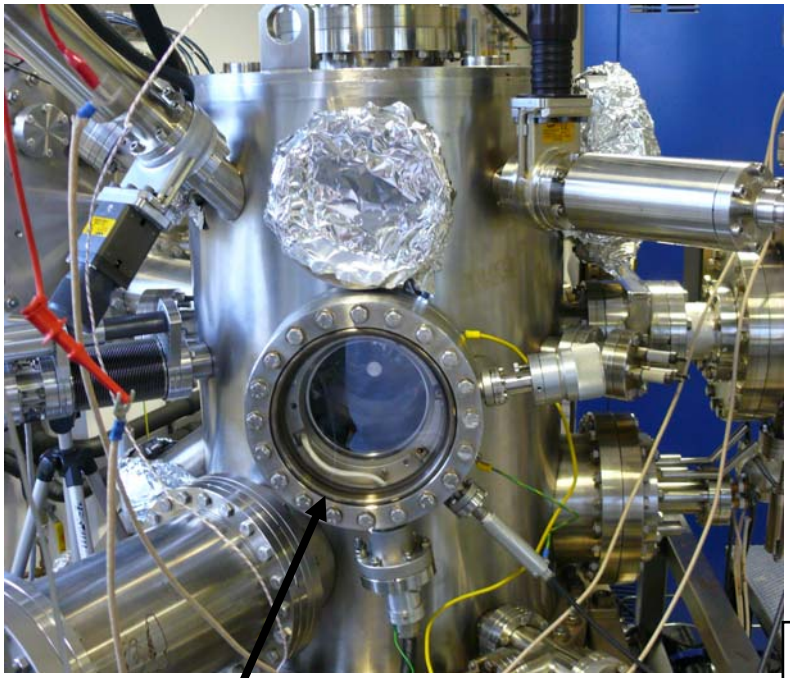

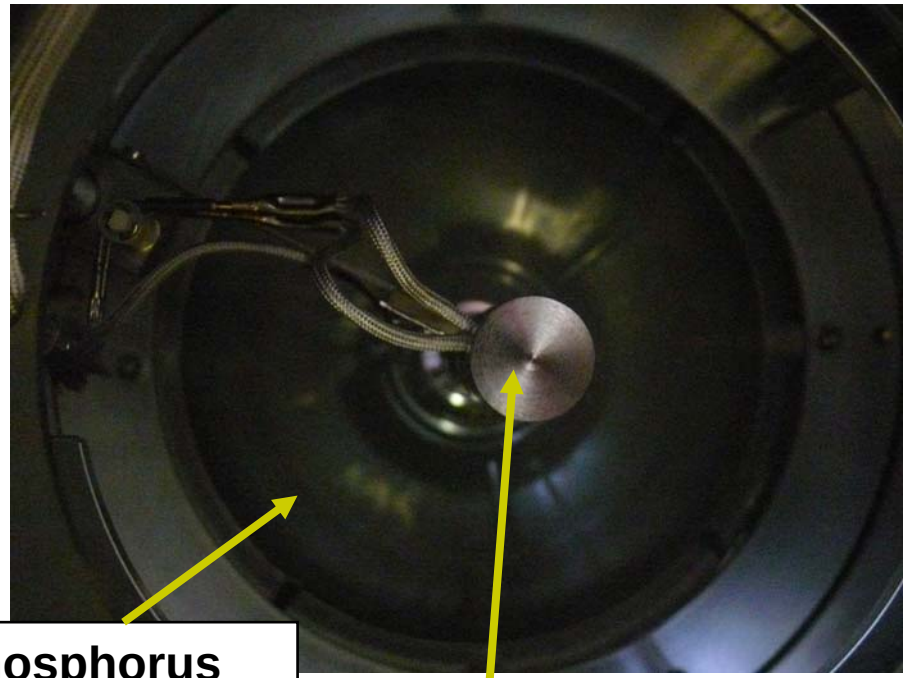

Phosphorus Screen

LEED

Electron Gun