# Elias Chatzitheodoridis

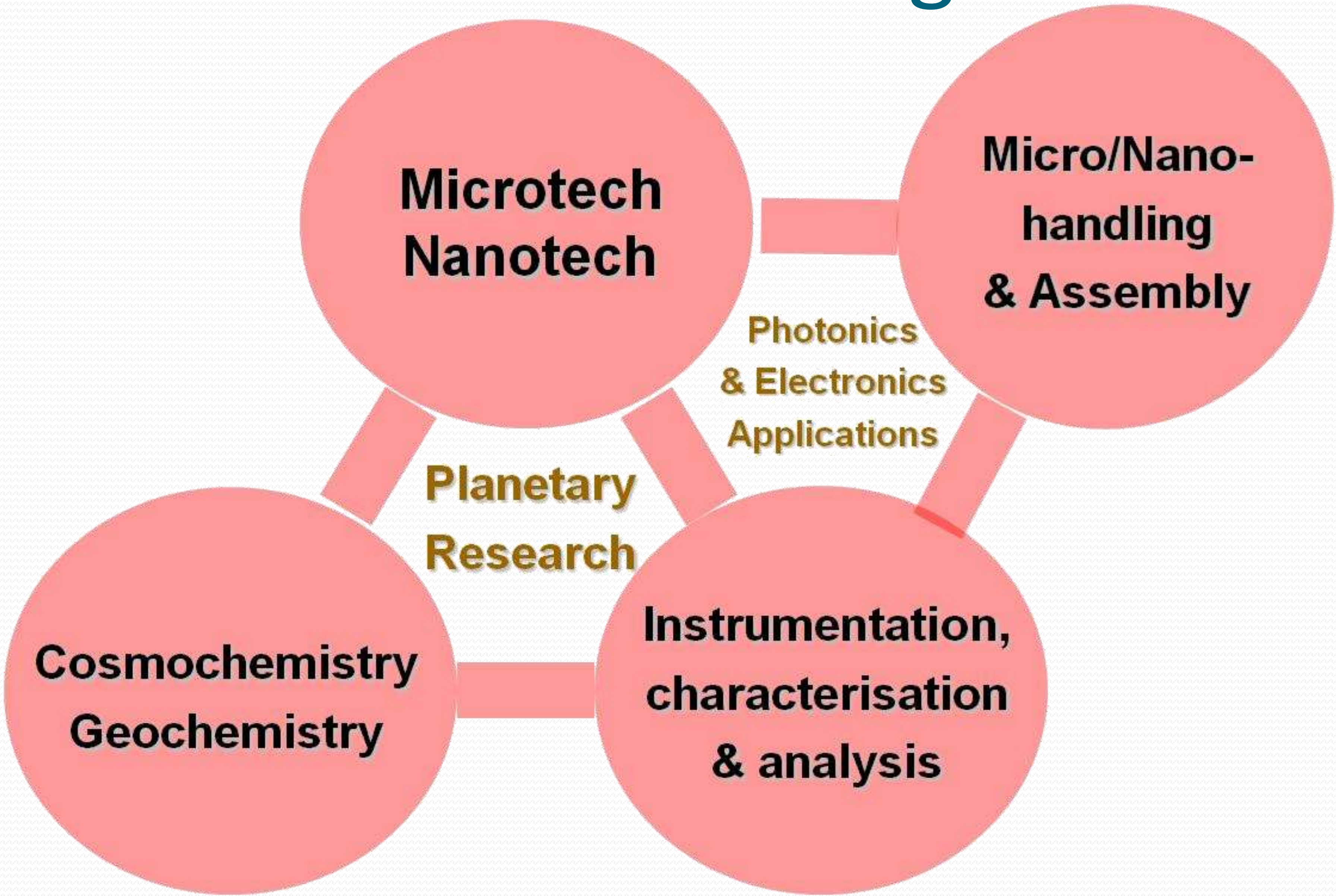
**Ph.D., M.Sc., B.Sc.**

A "visual" profile

Research interests and targets,
Experience and Qualifications

August, 2006

# Areas of interest and targets



# Brief profile

- Fully <u>interdisciplinary</u> character and experience ranging from natural sciences (space, earth, bio) to new technologies (micro, nano, computing, automation etc.)
- Determined for <u>innovation</u>, non-conventional thought
- <u>Organisational</u> & <u>Management</u> skills (e.g. vice chair experience for the European Commission)
- Quality <u>presentation</u> & <u>reporting</u> skills
- Flexibility in work, own initiatives, dedicated to achieve results of a high standard
- Open character to all cultures, friendly personality

# Micro- and Nanotechnologies
# Micro-handling and assembly

- Three-dimensional Photonic Band gap crystals: fabrication (using the **LiGA** and other micro-fabrication techniques) and characterisation (e.g. network analyser)
- Handling and Assembly of MEMS and other micro-devices
- Design and Fabrication of micro-handling tools (micro-grippers) and their actuation
- Three-dimensional (3D) structuring inside materials using femtosec-lasers

# Characterisation techniques and instrumentation

- **Static-SIMS**: commissioning and further development of a prototype SIMS instrument with multiple collectors and high mass resolution.
- **TOF-SIMS** mass spectrometry / Ion mapping
- **Raman** confocal microscopy
- **SEM** and **Optical** microscopy (including polarising/ petrographic microscopes)
- **X-Ray Diffraction** and other routine characterisation techniques

# Geochemistry, Cosmochemistry and Planetary research

- Meteorites from planet Mars
  - Astrobiology, biosignatures, extraterrestrial life
  - Secondary minerals in Nakhla (a meteorite from planet Mars).
  - Trapped Martian atmosphere in Nakhla meteorite with the use of noble gas mass spectrometry (Ar isotopes)
  - Oxygen isotopes in carbonates of the Nakhla meteorite
  - Trace elements in carbonates of Martian meteorites using sensitive, high-resolution TOF-SIMS analysis techniques
  - Micro-Raman analyses of carbonate and other minerals of Martian meteorites
- Oxygen isotopes in natural and space-exposed materials using Static SIMS techniques
  - Materials from the **LDEF satellite** (Long Duration Exposure Facility, NASA)
  - Authigenic quartz in oil-bearing sentiments of the North sea

# Other qualifications

- Highly proficient in computers and the Internet
  - Programming languages & techniques
  - Internet programming
  - Instrument control, automation, data acquisition, data manipulation
  - Main software packages, efficient in learning new ones
  - Some working experience with different mechanical or optical simulation packages as well as of CAD systems.
  - Quality presentation and publishing
- Understanding of Electronics
- Languages
  - Greek: mother tongue
  - English: fluent
  - German: Common communication skills, good level in reading
- Interdisciplinary general interests (natural sciences, technology, computing, electronics, chemistry & materials, space etc.)
- Inter/Multidisciplinary approach in problem solving
- Experience in project planning and technical management (through work in industry and from multiple European Network projects)
- Project evaluation and evaluation procedures (e.g. through several European project calls of Framework Packages)
- Organisational experience and methodologies for Transfer of Knowledge

# UNIT 1
# 3D Structuring in the volume of materials

- 3D demonstrators inside glass
- Gratings and 3D Photonic crystals
- Engraving of any image on the surface and inside the volume of materials
- A lithographic technology than could reach sub-micron levels, independent of the wavelength of the light beam used

Demonstration work that I did while working at **AT&S AG**, Austria.
The information provided here is not published.

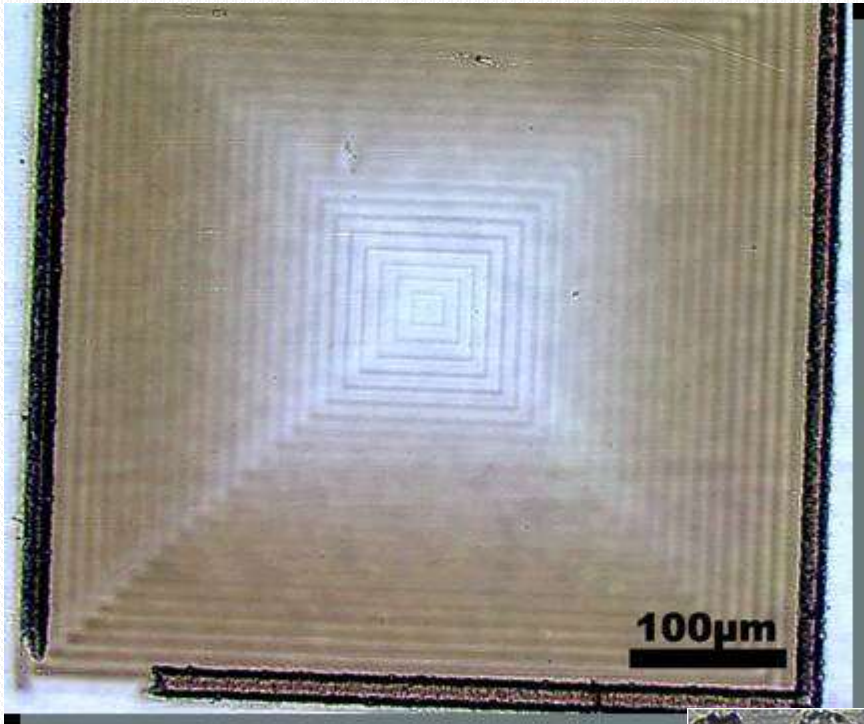
# 3D Structuring in the volume of materials

- I developed the full instrument setup and the full control software for true 3D structuring inside the volume of materials.
  - Step resolution: 20nm
  - Volume resolution:
    - **Hard materials:** sub-micron voxels (volume pixels) could be produced with better energy control which was not available to me at that time.
    - **Photo-resists:** 100nm or less voxels could be produced using two-photon absorption (not achieved yet, due to lack of precise attenuation of the laser beam, but possible).
  - 3D structuring: vector solid shapes or complicated multi-layered bitmaps.

- A number of demonstrators were produced
  - 3D vector shapes
  - Photonic structures with photonic effects
  - Artistic engravings, in the sub-mm scale, produced from bitmaps on the surface and inside materials.

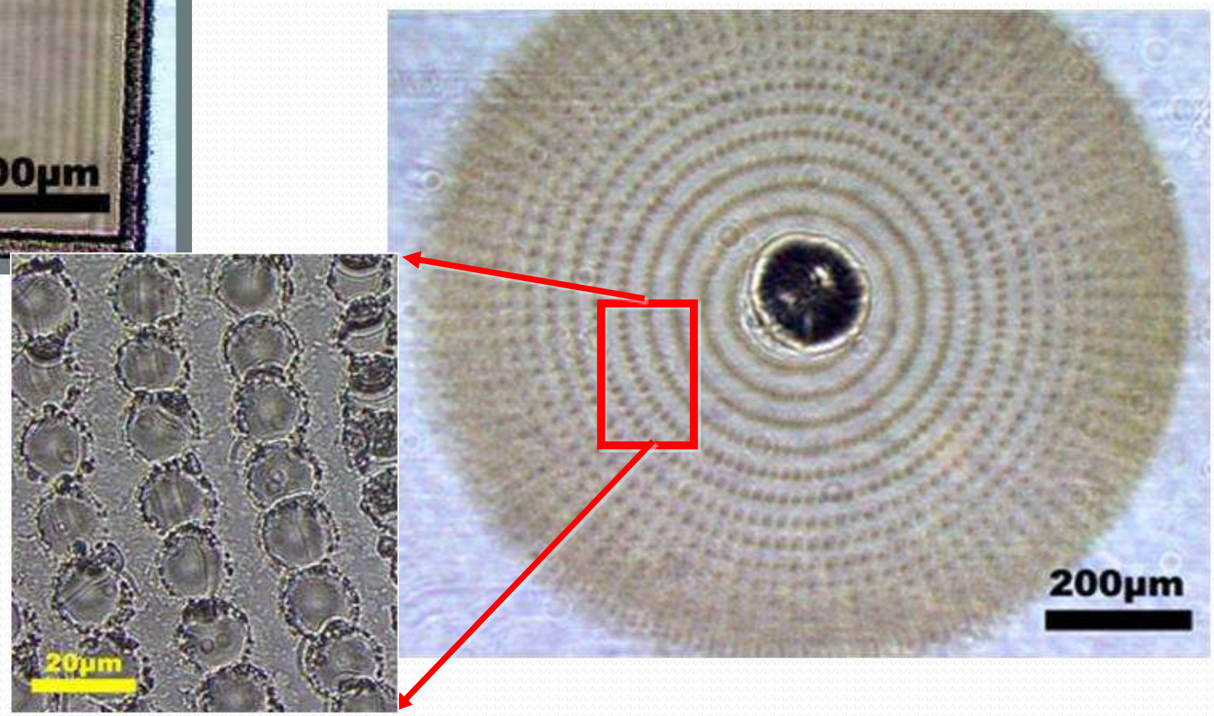
- Target applications of the methodology were:
  - Chip-to-chip optical communications
  - Planar optical structures
  - Photonic processing inside microchips.
  - Photonic processing and light control inside optical waveguides.
  - Precision machining, mask structuring, submicron surface cleaning etc.

# Structuring inside the volume of glass




## A pyramid inside glass

Largest/outer square is in the front side of the glass, while to top of the pyramid is on the other side of the glass, where also the focusing of the picture is.




## A sphere inside glass

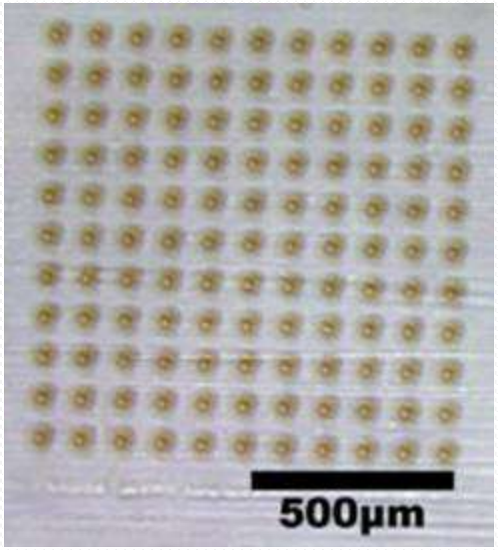
The focus point is deeper in the glass. A magnification shows the individual bubbles forming the sphere.

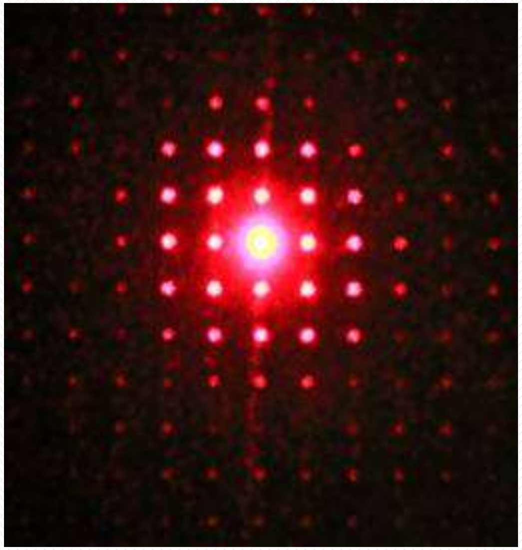
# 3D Photonic structures inside glass

**SC Photonic crystal (Simple Cubic)**

A 3D Simple Cubic photonic structure, periodic in 3 dimensions (the same pattern repeats 7 more times below this one).

Its diffraction pattern is seen to the right, produced with a laser at 633nm.

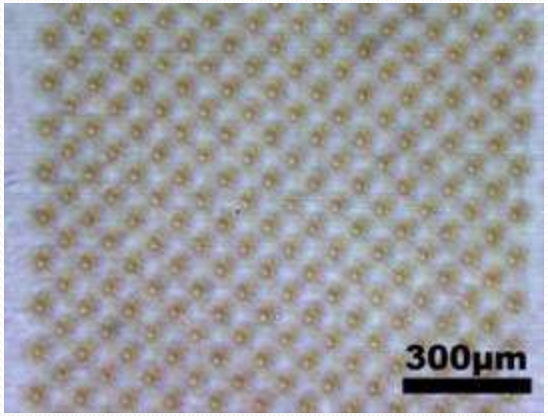


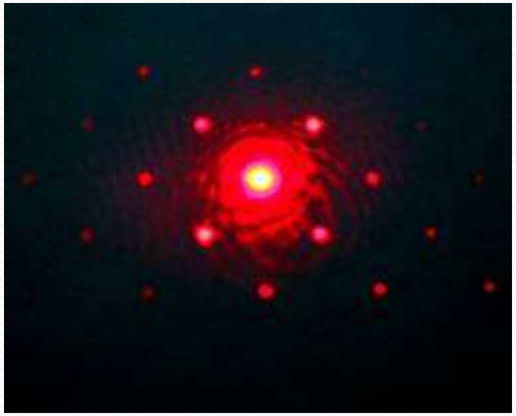



**FCC Photonic crystal (Face Centred Cubic)**

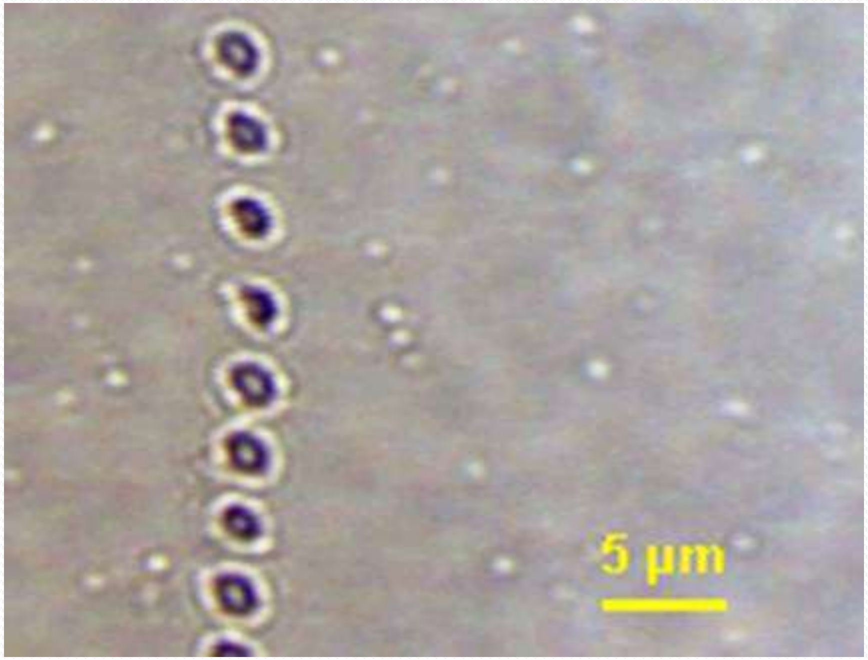
A 3D Face Cubic centred photonic structure, periodic in 3 dimensions (2 layers are seen here, the ones closer to  the surface of glass. The pattern repeat at 7 more layers deep).

Its diffraction pattern is seen to the right, produced with a laser at 633nm.



# Gratings inside hard materials

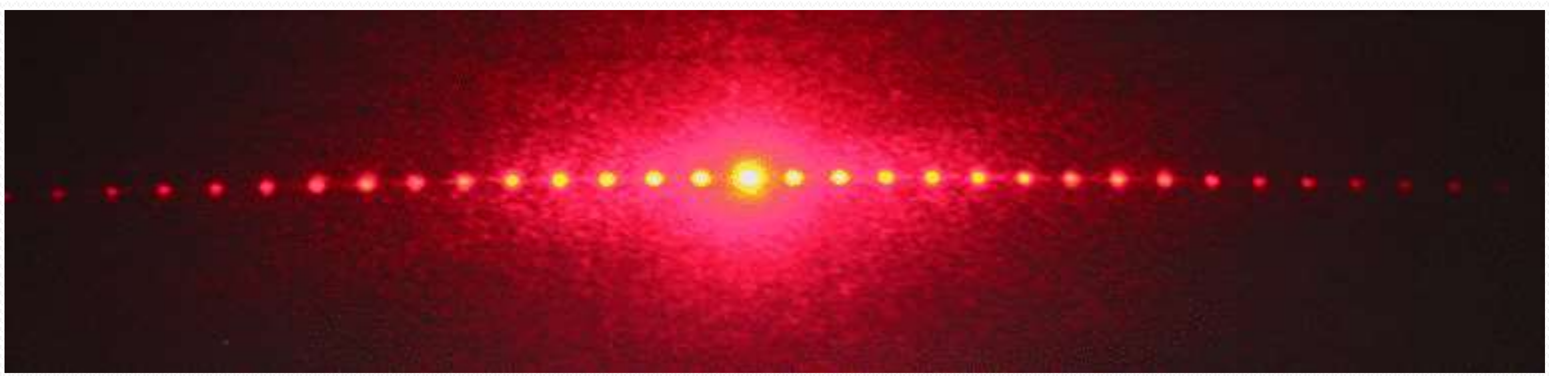



Voxels (volume pixels, bubbles) of less than 1.5µm diameter in sapphire substrate.

The bubbles are formed inside the volume of sapphire.

Better energy control -not available at the time- could produce bubbles of sub-micron diameters.

The above structure is a detail of a grating which produced the diffraction pattern seen below.



# Miniaturised picture engraving

Picture size of glass engraving 7×9mm

Eye detail

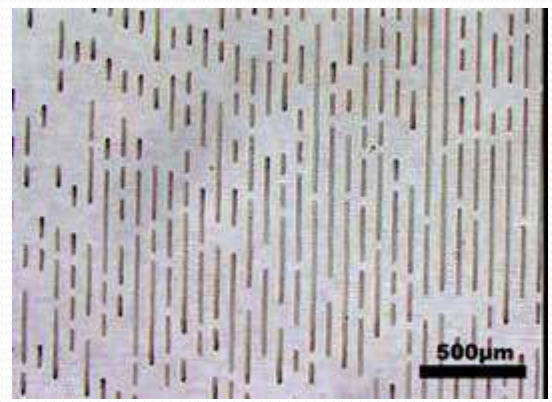
Nose detail

Einstein engraved on the surface of a glass slide.

The density of pixels is relatively high, demonstrated also in the two magnifications of the eye and the nose.

The same picture was also produced inside the volume of the glass material, however the poor quality of the glass produced colouring which resulted in a diffused image under the microscope, therefore it is not shown here.

Detail of a magnified version of Einstein on glass with smaller density of pixels.



# UNIT 2
# Photonic band gap crystals (PBGs)

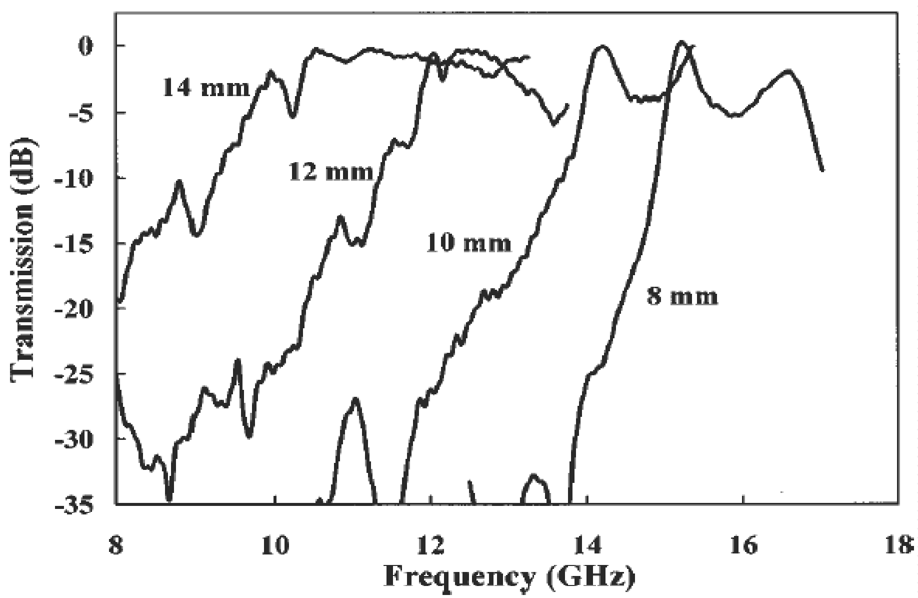
An effort to fabricate full three-dimensional artificial crystals with a variety of technologies.

Most work was performed under EU projects and funding.

# Photonic band gap crystals (PBGs)

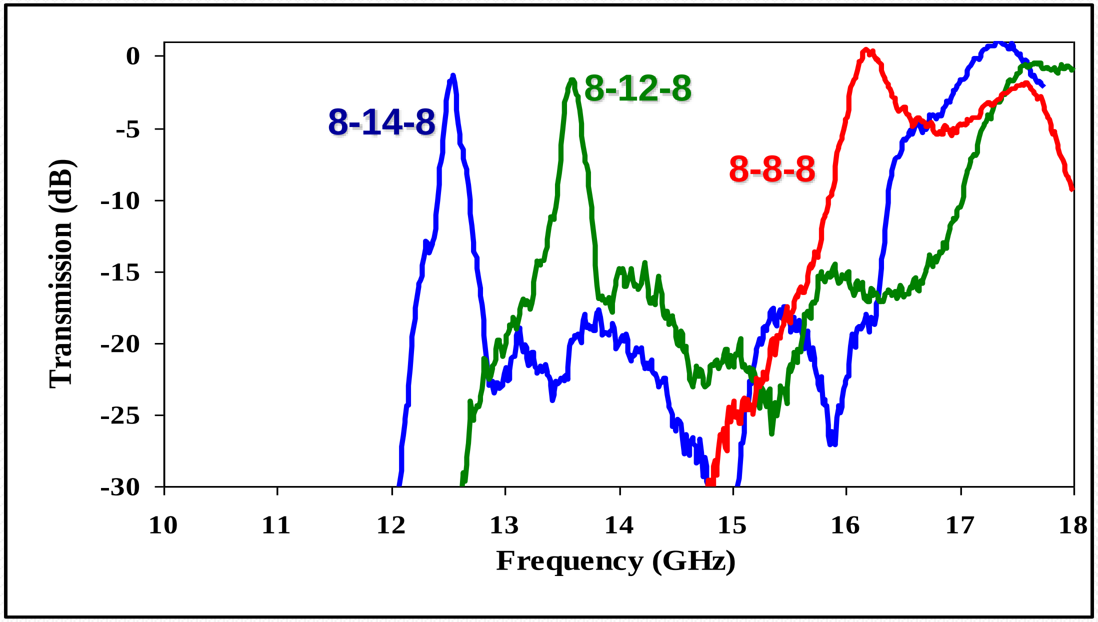
- Microtechnologies were used to fabricate the artificial crystals
  - **LiGA** technique
  - Mechanical machining and electroplating
  - Laser machining
  - 3D Laser writing inside the volume of materials
  - Micro-assembly of microstructures
- Some of the structures were successfully characterised using a network analyser.

# PBGs for microwaves




Cut-off frequency as a function of hole diameter

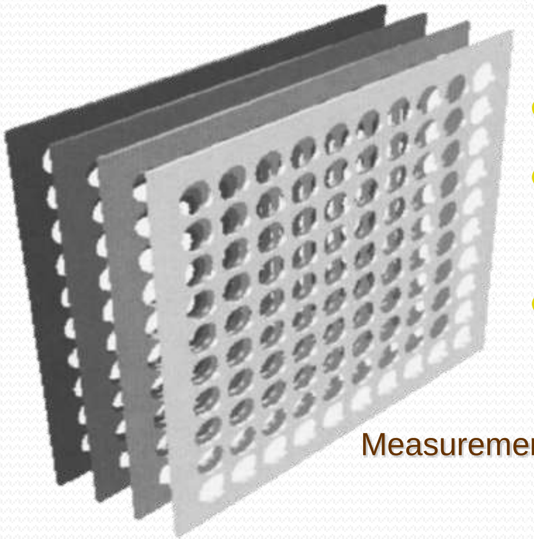
Structural defects produce peaks in the filtered area




8-8-8 Periodic structure with 3 plates of 8mm diameter holes

8-12-8 Structure with defects (middle plate with 12mm holes)

8-14-8 Structure with defects (middle plate with 14mm holes)



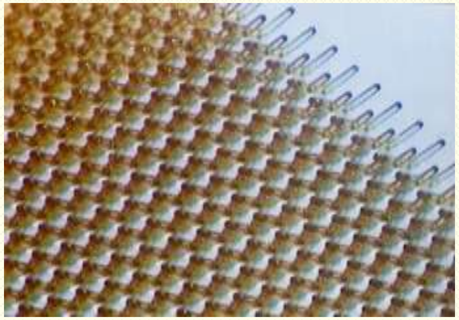
- This is a laser-machined structure of a 3D PBG (15cm plate size).
- The structure was made modular to produce periodic structures or structures with defects.
- The results shown in the graphs above are some of the properties of these structures (measured by network analyser).

Measurements were performed at **Iowa State University, Ames Labs., USA**, while fabrication was performed in **Greece**, **FORTH/Crete** and **Laser Innovation Centre/Athens**.

The work was supported by NATO and was performed within the MICROSYNC/TMR/EU Network Project

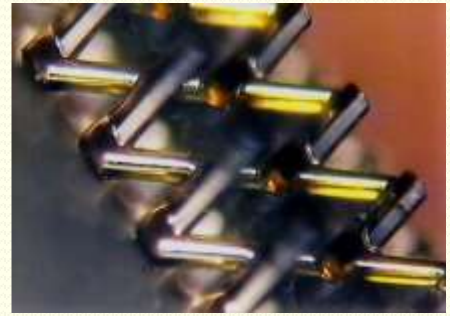
# PBGs with the LiGA technique

## Negative resist (Novolac) structures



**25µm**

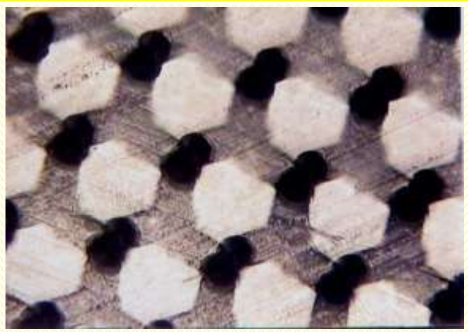
**Rod diameter**



**100µm**

**Rod diameter**

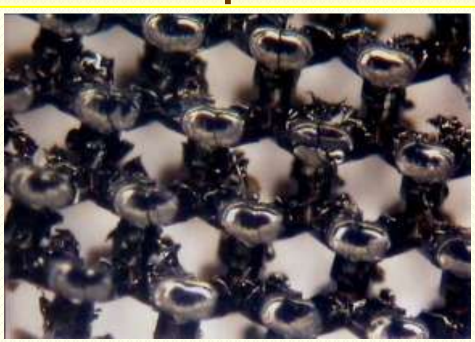
## Positive resist (PMMA) structures



**25µm Rod diameter**

These structures (and the Novolac ones) do not have the required refractive index contrast to open a band gap and, therefore, are filled with other materials (see below).

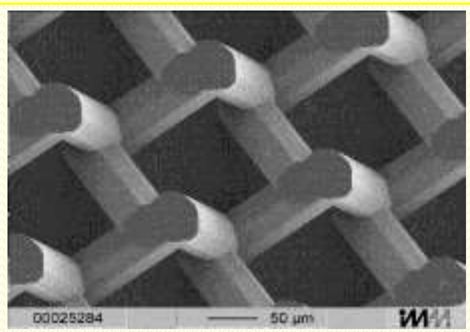
## Structures produced after filling the PMMA structures and then removing the PMMA

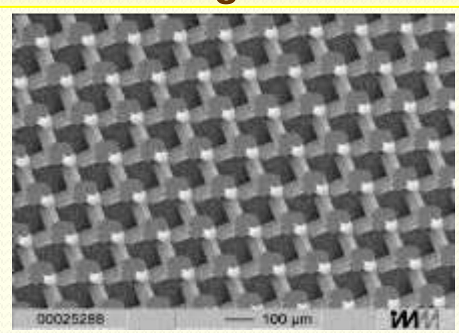


Ceramic (SiC) Structures.

**100µm**

**Rod diameter**



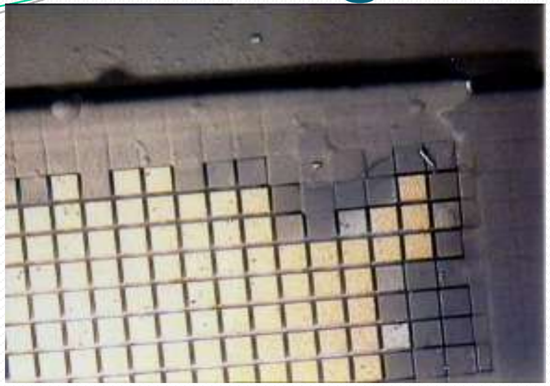


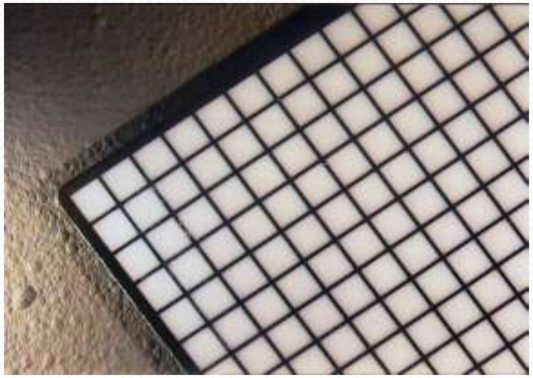
Metallic (Ni) Structures.

**60µm**

**Rod diameter**

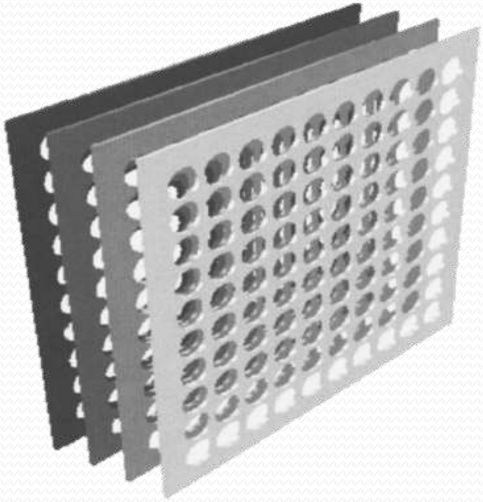
# PBGs using other fabrication methods





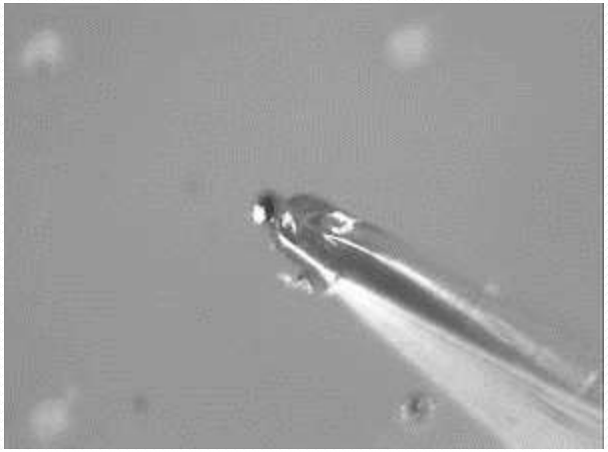
Mechanical machining of $Al_2O_3$ (with a disc-dicing system), sputtering and electroplating was used to fabricate these structures. Stacking more than one of the structures results into 3D PBG structures.

(100μm metallic bars distanced by 1mm)



Laser-cutting of large stainless steel plates was used to produce these modular PBG structures successfully used to filter out microwaves.

Assembly of copper micro-spheres in an ordered way in free or on templates has been tested to produce PBGs. A time consuming method which requires full automation to succeed.

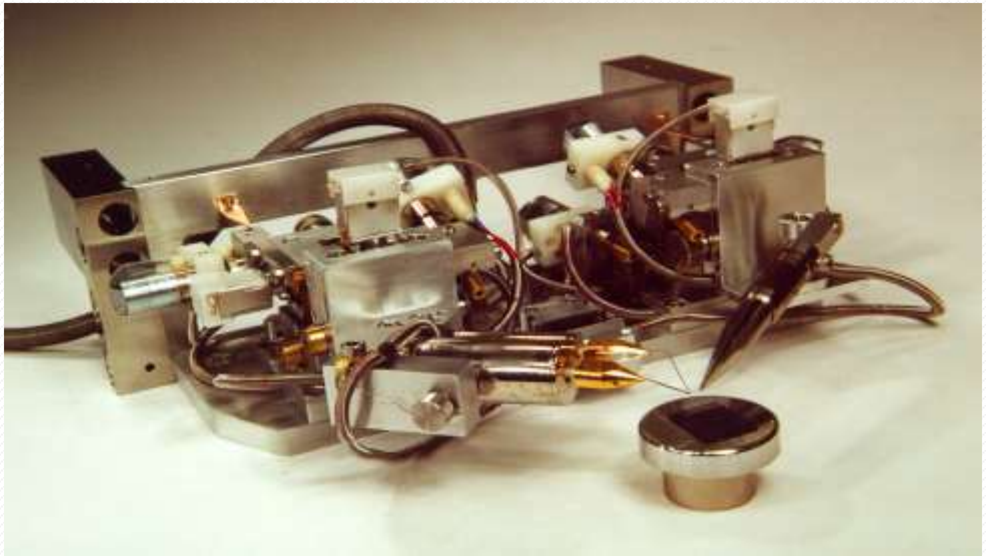


# UNIT 3
# Handling and Assembly of MEMS structures and devices

- Automated assembly with basic robotics and pattern recognition
- Assembly under vacuum conditions (SEM microscopes)
- Fabrication of gripper tools
- Software development

# MEMS handling and assembly in the SEM chamber

We tested an already existing prototype of a twin-arm system with two grippers, which could fit inside the chamber of an SEM.



The experience acquired from this system led to new ideas and the development of another handling and assembly system, which was easier to use.

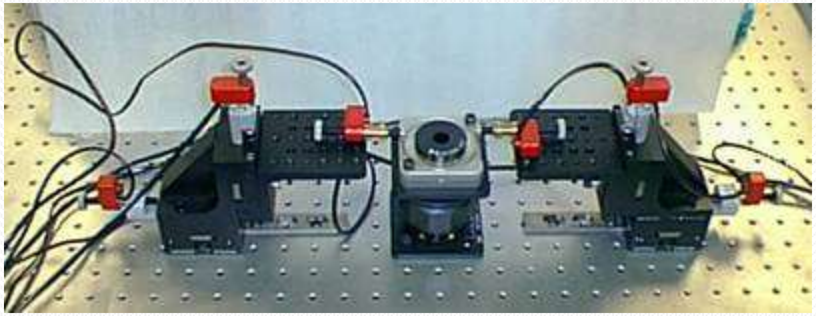
The new system is developed under the EU network HAFAM.

**http://www.ifwt.tuwien.ac.at/hafam/**

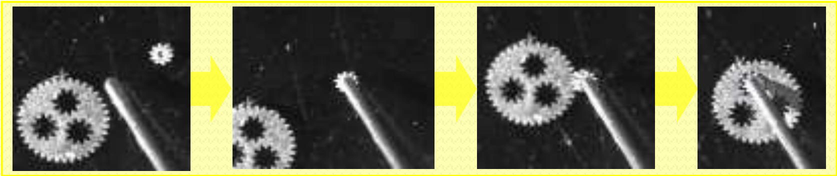
# A new system for MEMS handling and assembly in the micron and submicron scale

- Motors with step resolution of 30nm, based on the piezoelectric effect.
- Assembly could be manual with a 3D mouse or joystick, or semi-automatic (the system assists in precision jobs removing the strain from the operator and minimising errors).
- Software control using a 3D mouse, based on new software technologies, upgradeable or easily rearranged according to the hardware, with several tools linked with drag-and-drop operations (fully developed by me).
- Microparts are automatically located and learned by the system, based on real-time image processing and pattern recognition.
- Microparts are also automatically positioned using the same pattern recognition system.
- Mistakes or sudden location changes of the microparts is still automatically recognised by pattern recognition.
- The full system is very small and could be further minimised to easily fit even into a small SEM chamber, and to be compatible to vacuum systems, while it is controlled from outside with many degrees of freedom.
- A variety of grippers can be attached to the arms:
  - Under room conditions or under liquids, vacuum grippers of a variety of sizes have been attached and tested.
  - Under any conditions mechanical grippers of any size could be attached. Two designs of grippers have been fabricated and tested with the system, one employing a force sensor based on optical control (another member of my group and me created and optimised the designs of the grippers and then produced them outside with the μEDM technique).

# Photo shots of the miniaturised assembly system and the grippers

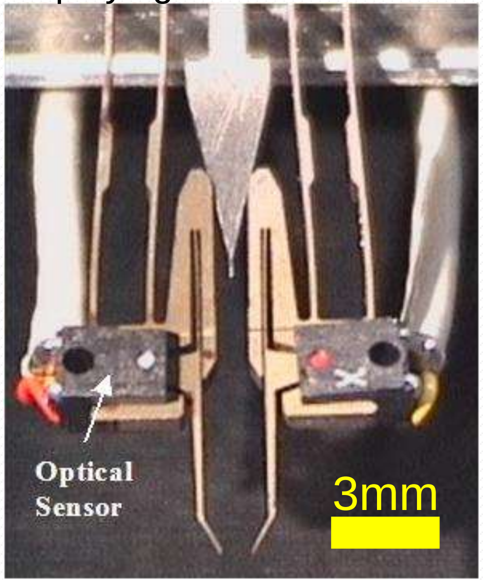


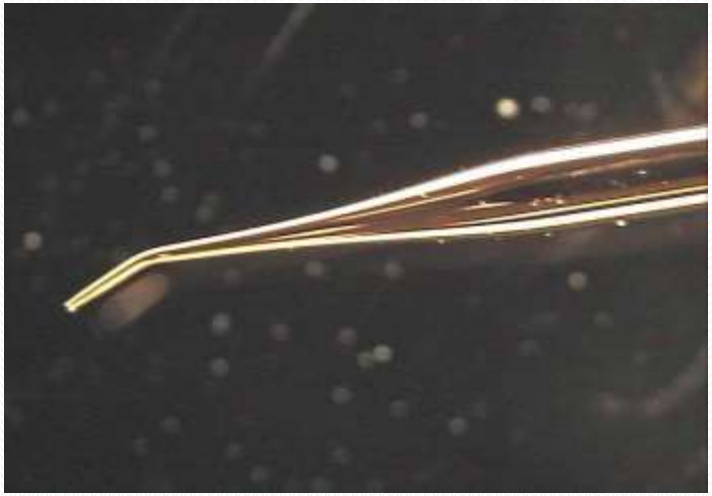
Basic configuration of two stages with piezo-motors 3 degrees of freedom each and a middle rotational stage.



Fabricated vacuum/suction gripper demonstrating assembly of micro-gears, which were produced by LiGA.

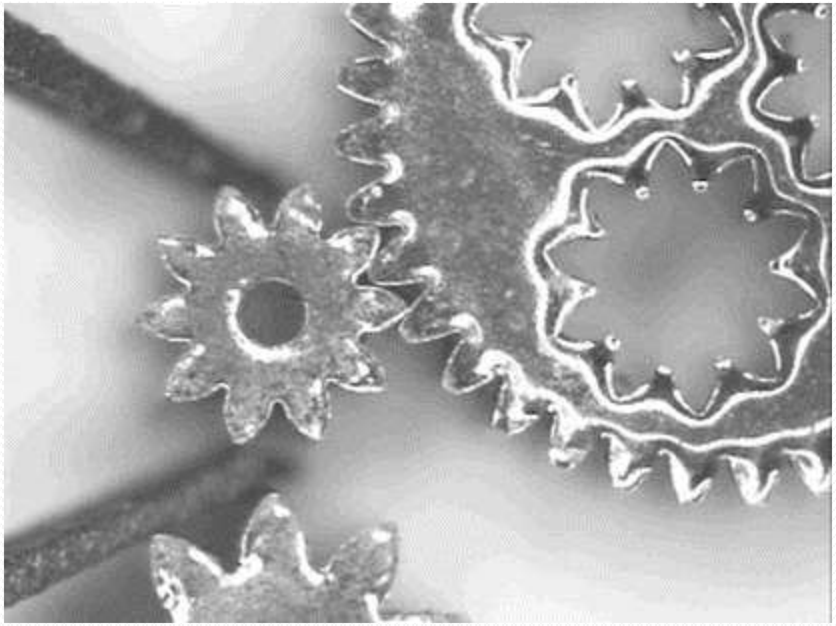
Mechanical gripper, electrically activated employing force sensors.



Commercial vacuum/suction gripper (used in genetic experiments) and plated with metals in our labs to reduce electrostatic effects.
This was tested for assembly of features with sub-micron and up to a few microns size.

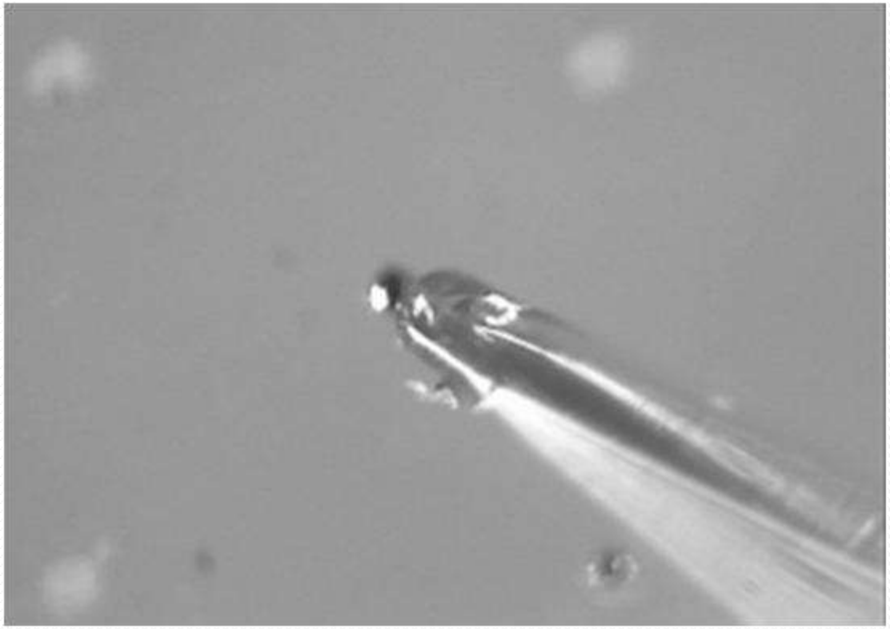
# Tools and microparts



The two arms of the mechanical gripper pick a micro-gear (made by LiGA) and assist in the assembly of the gearbox.

Gears are provided and fabricated at IMM/Mainz/Germany

The small gears are about 0.5mm diameter.



The glass vacuum/suction gripper picks a copper micro-sphere.

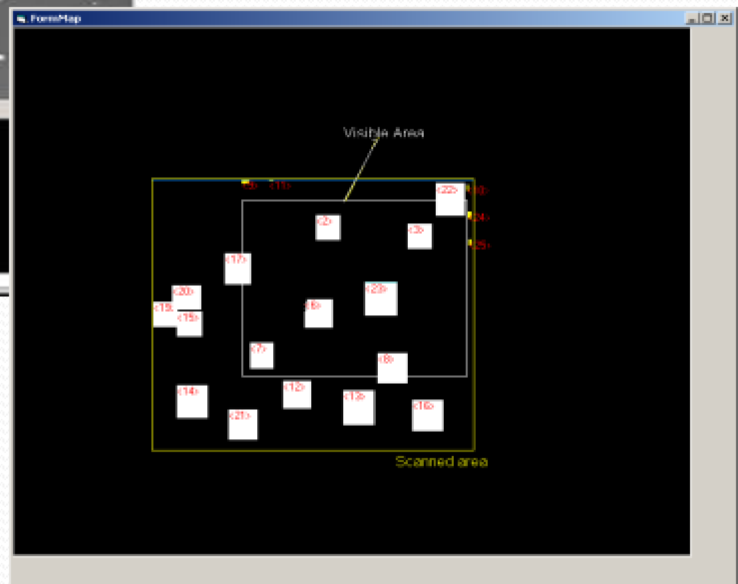
The size of the micro-sphere is about 5µm

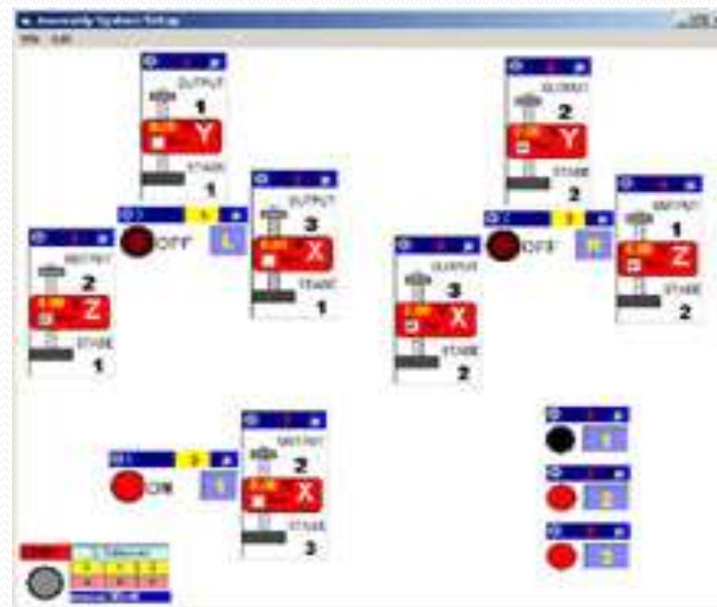
# Control software of the assembly system

The pattern recognition system recognises and follows the gripper arms. The microparts are also recognised and an image-model is saved below for different parts.

Each micro-part that drops into the viewing area as the stage moves is also recognised, linked to an existing or new model, and its coordinates are saved on a map (below).

The original concept is from me, software and further enhancements were made by me and one more person of my group.



The control screen of the assembly system. Every icon has a physical device (motor, stage, switch or 3D-mouse). Functionality is achieved by linking the icon properties with drag&drop operations. A fully modular, upgradeable and open system.

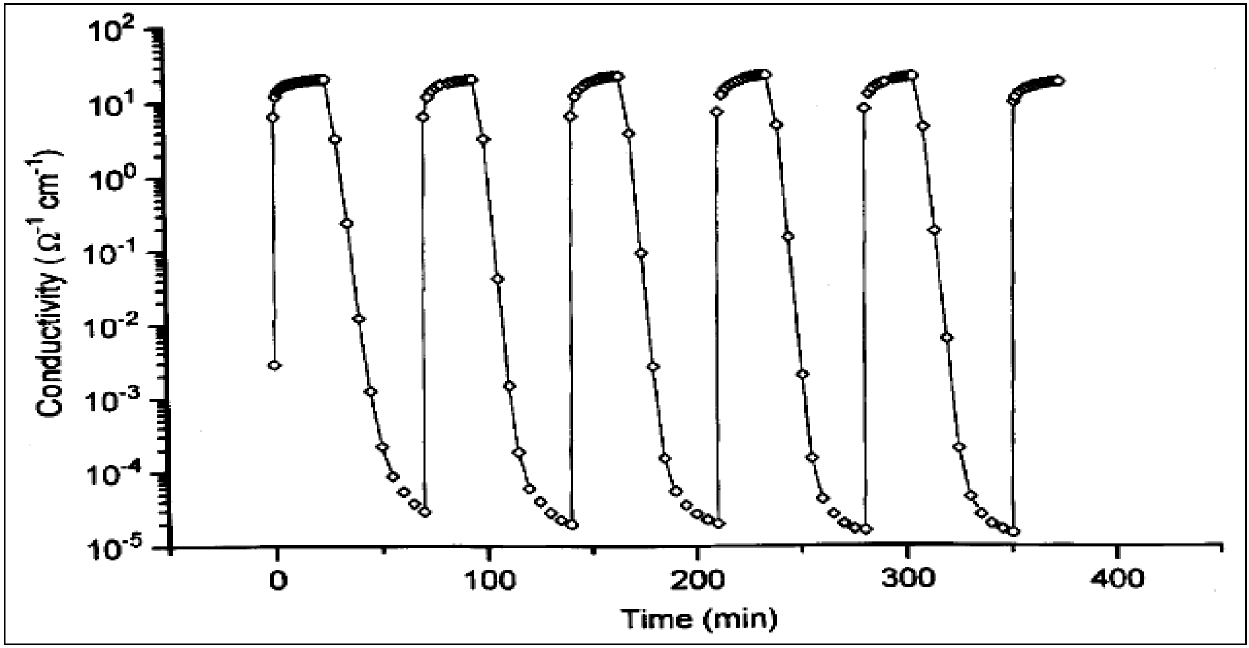
Concept and software were developed by me.

# UNIT 4
# Materials science

Growth and characterisation of the chemical, structural and optical properties of thin films

# Growth and characterisation of polycrystalline Indium Oxide thin films.

- I was involved in growing Indium Oxide thin films with DC-Magnetron sputtering and in their characterisation.
- Special properties included:
  - Localised change of conductivity, which could change in unlimited cycles in a controlled way (later it was proved that it was only a surface effect).
  - Localised change of refractive index with applications in holographic recording.
  - The above two effects seem to be related



# UNIT 5
# Study of Martian meteorites

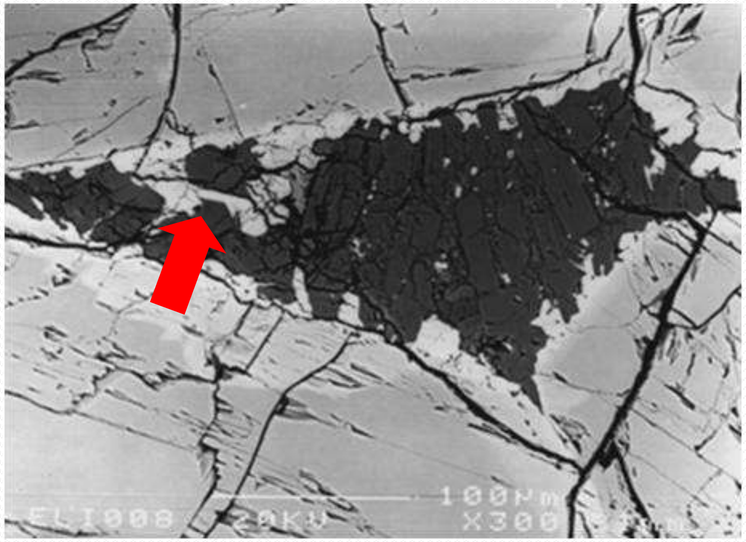
An effort to investigate in detail the environment of planet Mars and the possible presence of life

A study which started with my MSc work, continued with sporadic efforts after my PhD and performed further now in close collaboration with Manchester University, Earth Sciences Dept., Isotope Geochemistry and Cosmochemistry Group

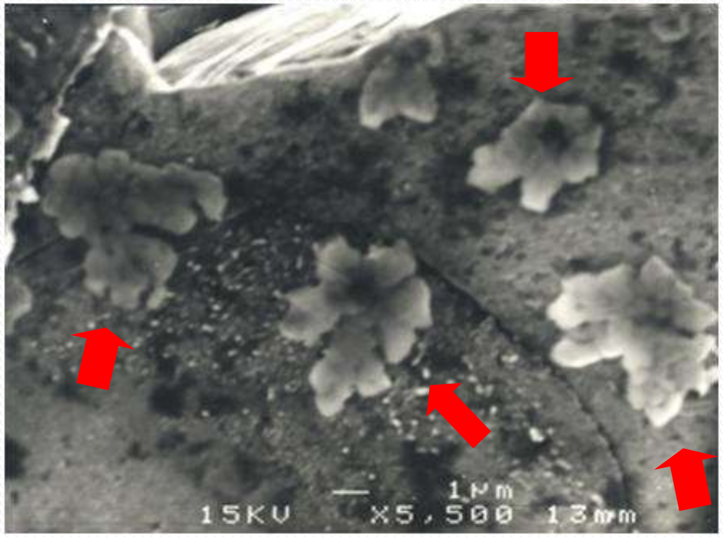
# Study of Martian meteorites

- Secondary minerals in the meteorites
  - First to find and report the siderite carbonate in Nakhla
  - Among the first to find and report halite (NaCl), sulphates and carbonates in Nakhla
- Search for trapped Martian atmosphere in secondary minerals of Nakhla, using noble gas mass spectrometry
- Oxygen isotope studies in carbonates of Nakhla using very sensitive, high mass resolution, multi-collection static SIMS techniques
- Study of the carbonates in ALH84001 (currently running)
  - Mapping of trace elements using high-mass resolution TOF-SIMS (chemical and isotope 2D and 3D maps)
  - Raman microscopy characterisation of the phases
- Systematic Study of a variety of Martian meteorites (Nakhlites) using Raman microscopy, TOF-SIMS, SEM, FE-SEM, AFM, TEM etc.
- Unique finding of possible bacterial fossils in Nakhla meteorite (only visual evidence till now, not published)

# Secondary minerals in Nakhla



Siderite carbonate in mesostasis

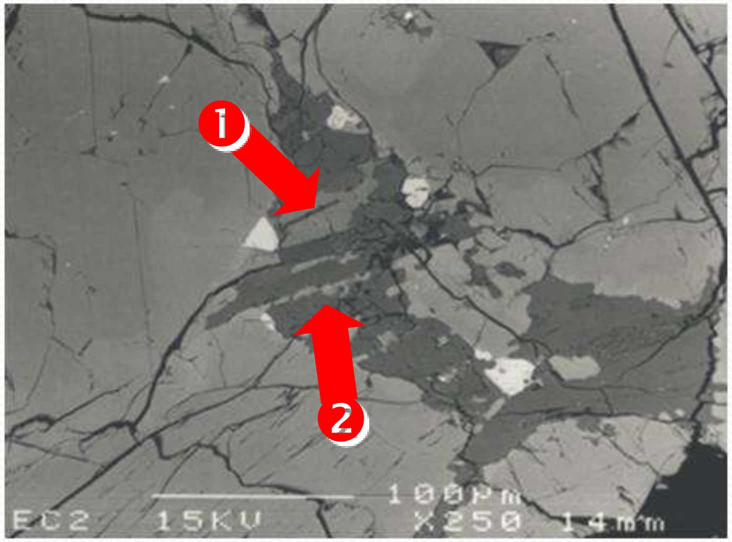


Halite (NaCl) on eroded pyroxene surface

SEM backscattering images of secondary minerals in Nakhla meteorite

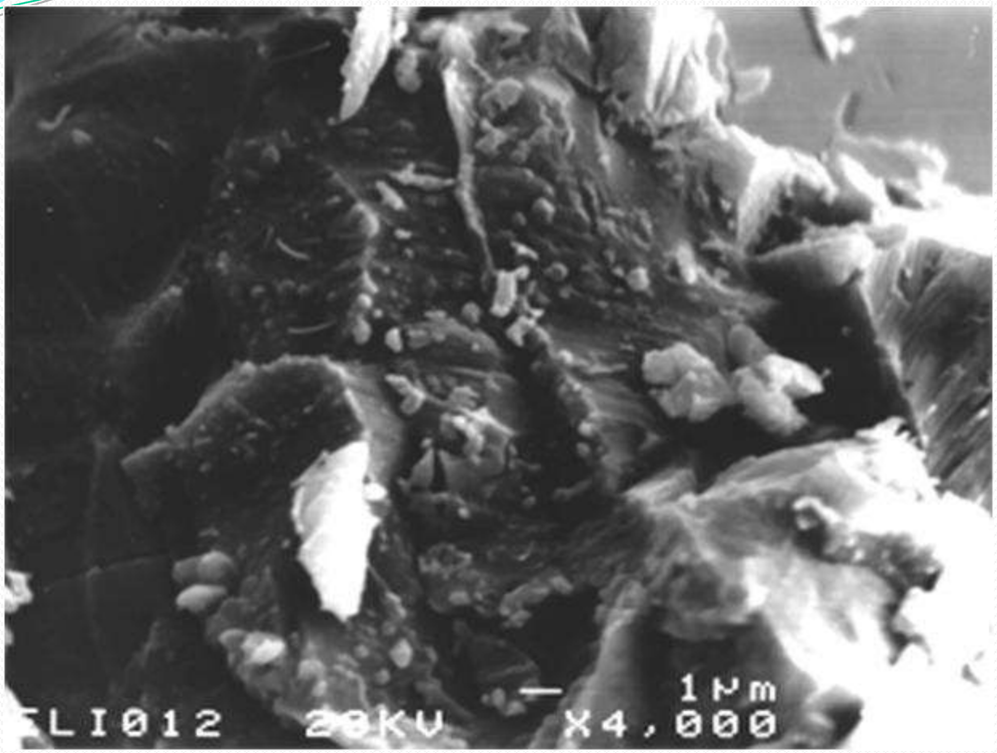
Top-right: from a grain

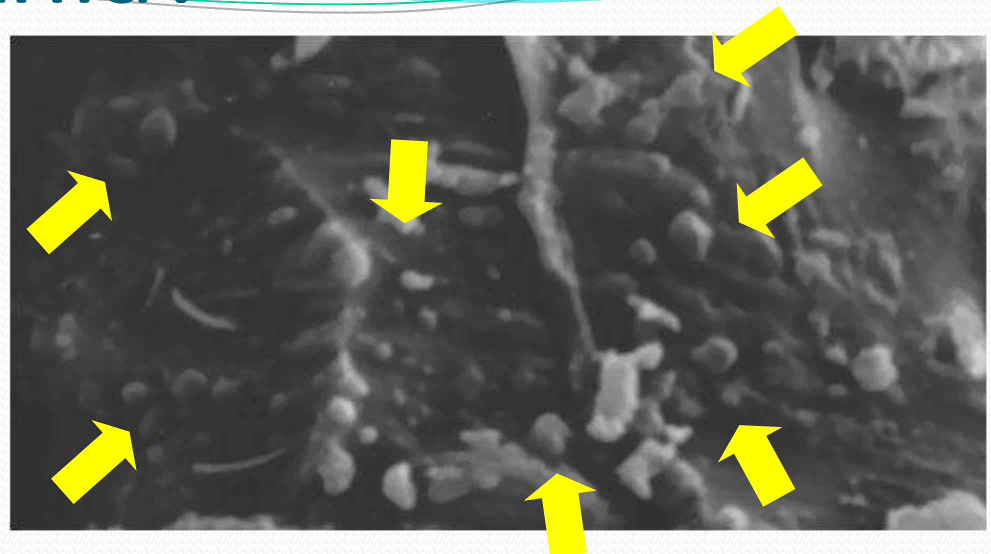
Top-left & Bottom-right: from thin sections

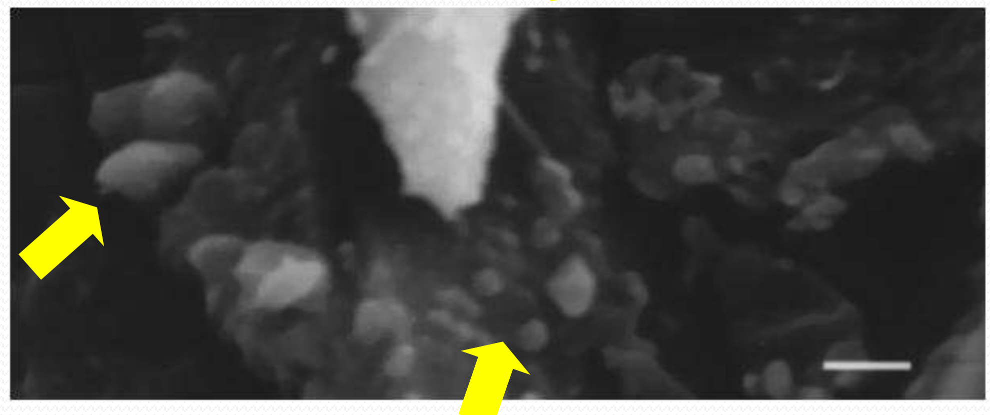


❶=Anhydrite, ❷=Carbonate

# Bacteria fossils in Nakhla?



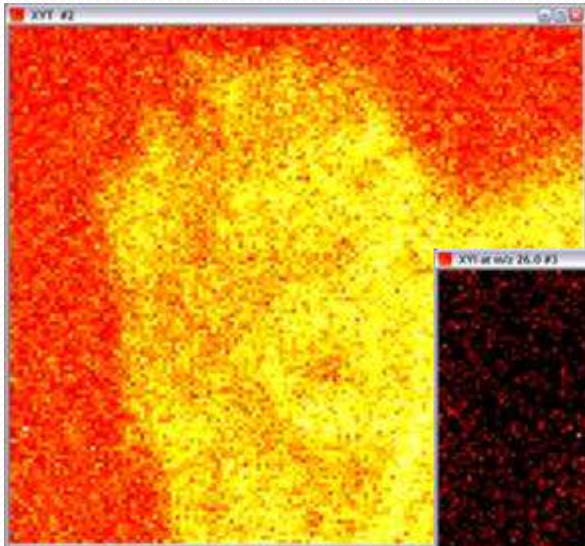


Spherical structures of 0.5 to 1μm are distributed in this area. Their composition is sulphate ($Ca_2SO_4$) which is secondary in origin. In any case, their form suggests evaporitic processes, which on Earth they include water.

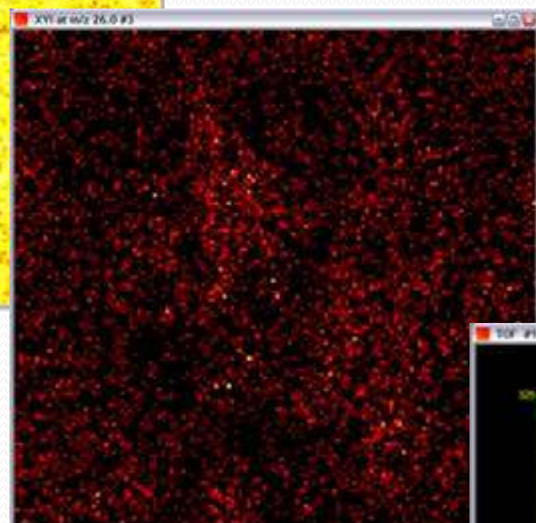
# <u>New</u> evidence for life on Mars?

- Nakhla samples under investigation contain <u>**a very peculiar structure**</u> which according to structural and mineralogical evidence <u>**it could be a large form of life**</u>!
- In the same thin section, other secondary minerals were found such as **carbonates**, **sulphates** (showing also <u>water Raman bands</u>), and **halites**.
- The current work includes:
  - SEM imaging and WDS and EDX analyses
  - TOF-SIMS ion maps and search for biosignatutes
  - Raman analyses
  - AFM imaging
  - TEM analyses
- <u>**The information is under preparation  for publication!**</u>

# Element and Isotope Mapping

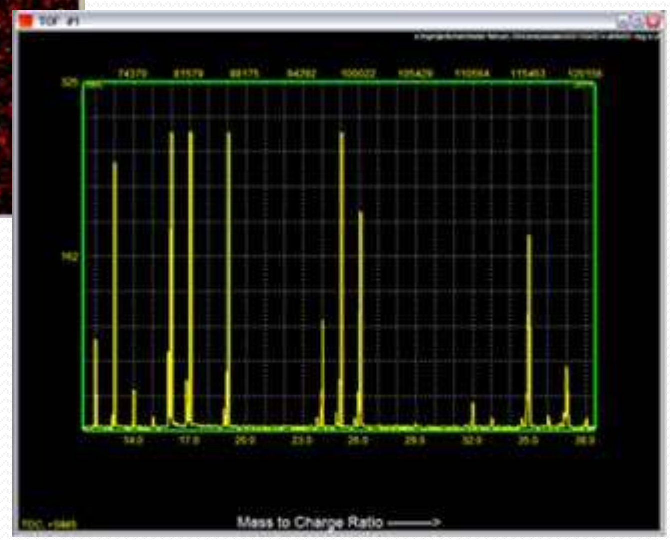


**Total element map**



**Fe-element map**

The TOF-SIMS of Manchester University, Earth Sciences Dept.



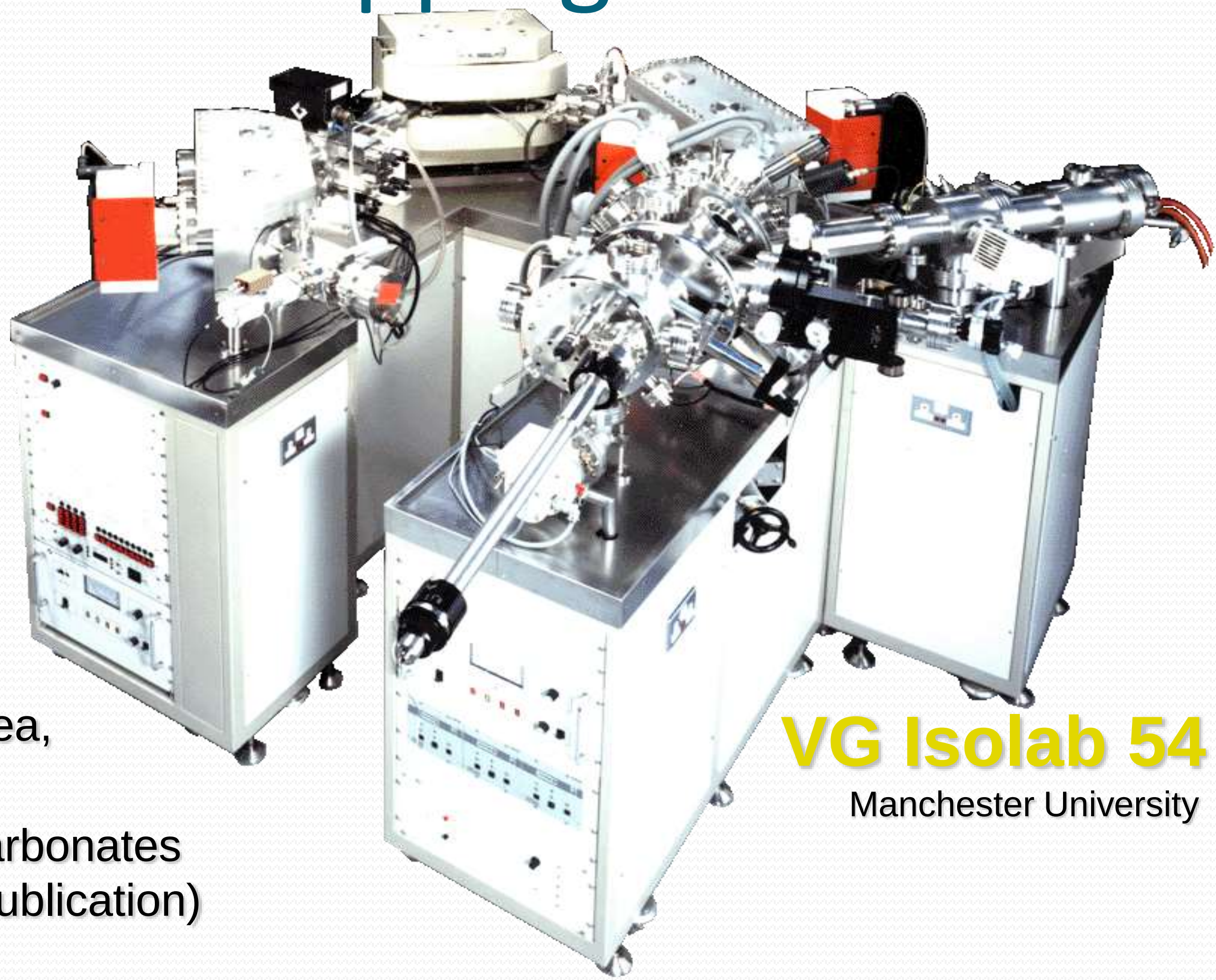

**A TOF-SIMS mass spectrum**

Current analytical work performed with TOF-SIMS on Martian meteorites.

Work is made in collaboration with Manchester University and at their laboratories. To manipulate the images I developed specialised software (see later slides).

# Isotope analysis and mapping

- Assisted in the commissioning of the IsoLab 54 multi-collection, two-stage ion probe (PhD).
- Developed the method for oxygen isotope analysis (PhD)
- Studied samples of the LDEF (Long Duration Exposure Facility Sattelite) and compared with isotopic fractionation models of the terrestrial atmosphere.
- Studies on samples from North Sea, previous oil reservoirs (PhD).
- Studied the oxygen isotopes of carbonates in Martian meteorites (PhD and Publication)



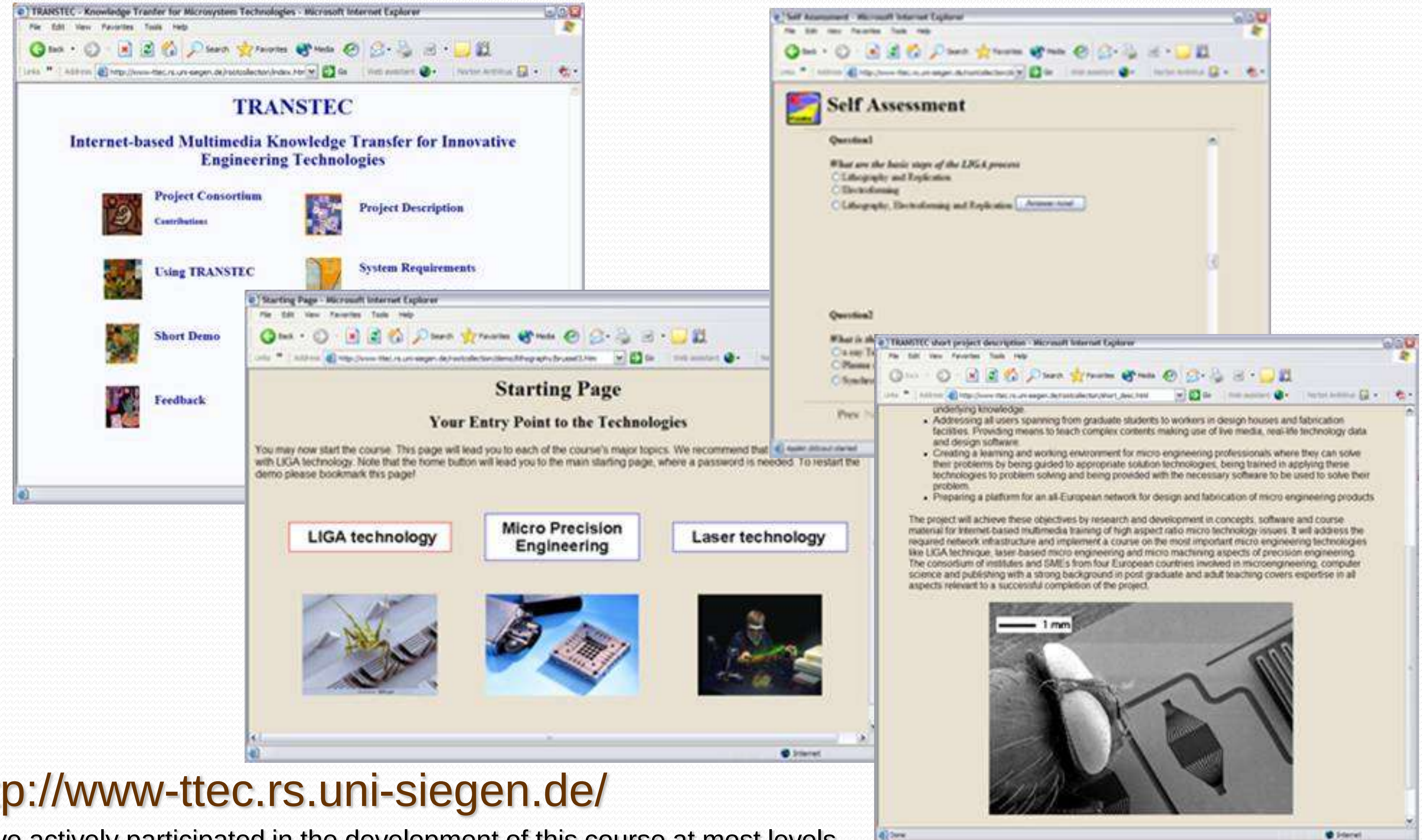
**VG Isolab 54**

Manchester University

# UNIT 6
# Distant Educational Tools & Web Technologies

- Microtechnologies
- Crystal Symmetry
- Optical properties of materials & microscopy
- Mineralogy & Petrology
- Realistic simulations of light transport
- Interactive web material

# Distant Educational Tools & Web-Technologies for Microtechnologies

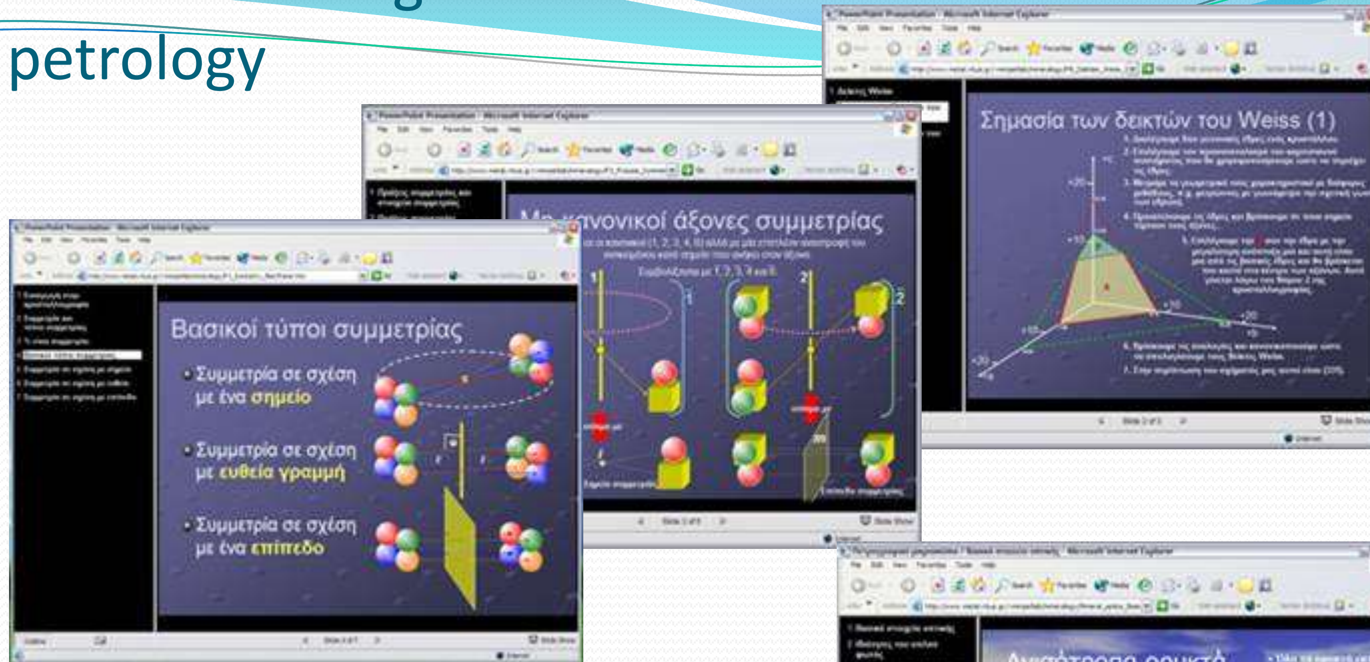



http://www-ttec.rs.uni-siegen.de/

I have actively participated in the development of this course at most levels

# Distant Educational Tools & Technologies in crystallography and petrology

Symmetry & crystal structure




Optics,

Microscopy,

Optical mineralogy

Properties of minerals


**http://www.metal.ntua.gr/~minpetlab/**

**(in Greek)**

**This work is entirely made on my own efforts.**

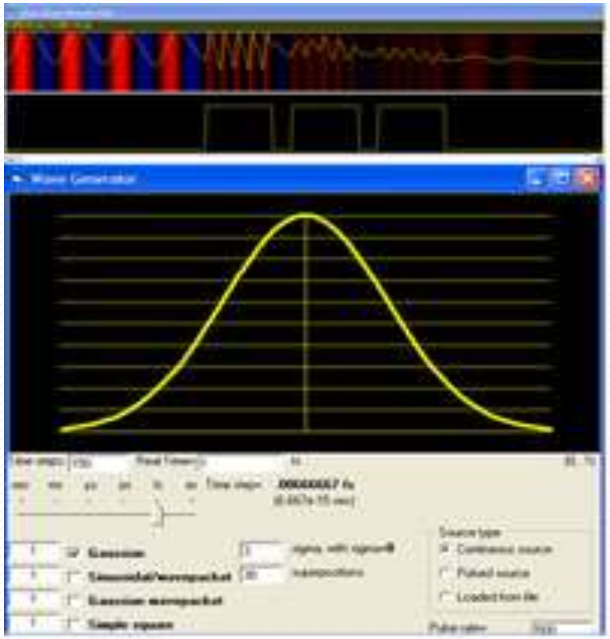
# Distant Educational Tools & Technologies

## Interactive material

Interactive web-pages for teaching mineralogy and petrology

http://www.metal.ntua.gr/~minpetlab/

(in Greek)



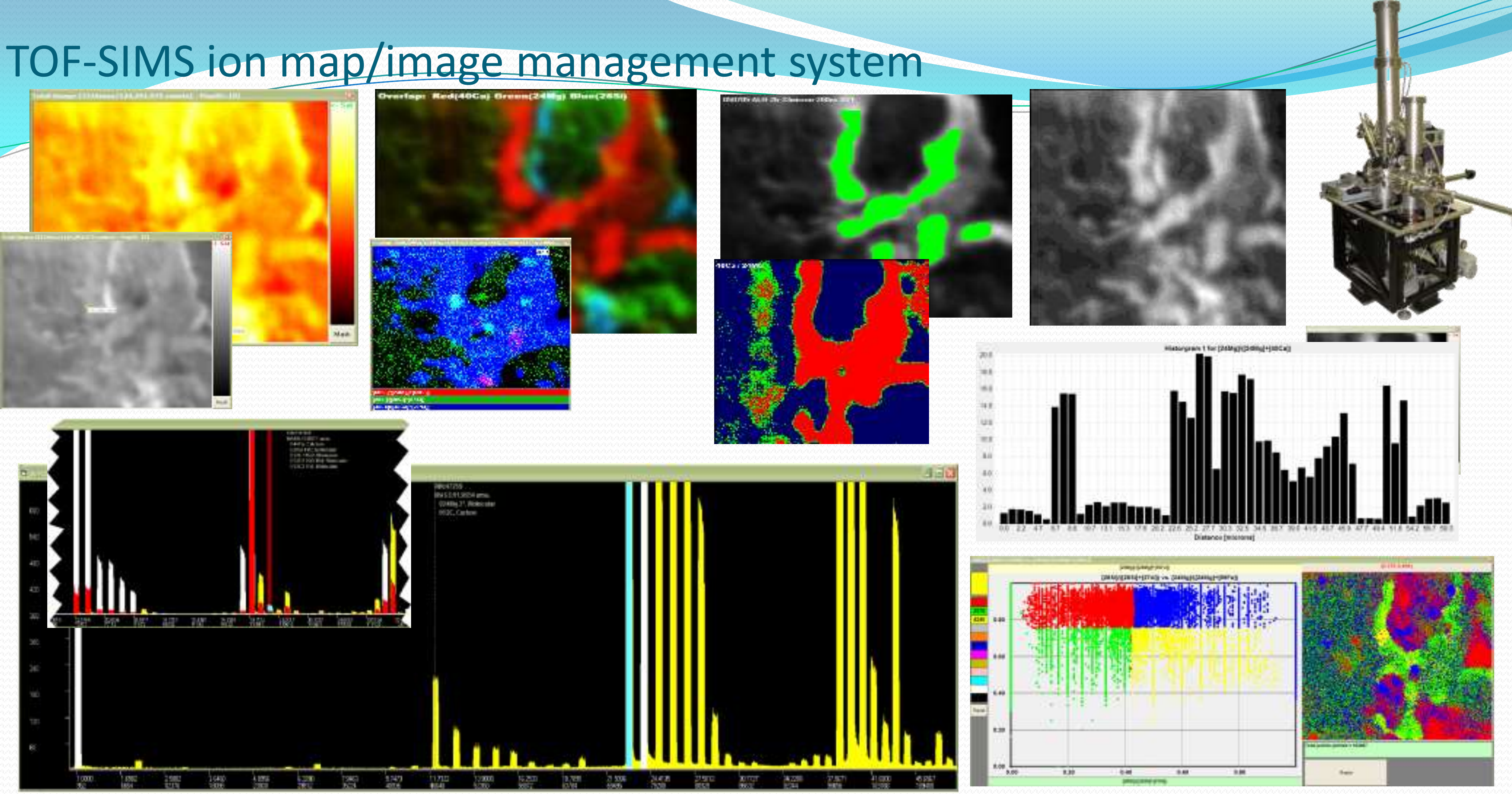
Realistic computer simulations to demonstrate light transport inside materials with pulse and wave generators

This work is entirely based on my own efforts.

# UNIT 7
# Additional activities

- Development of a TOF-SIMS ion map/image management system
- Development of an application to handle all related analytical data (sample-oriented).
- Development of an unattended software system assisting me in bibliographical search and archiving
-Technical evaluations for the European Commission
-Invited Lectures on microtechnologies

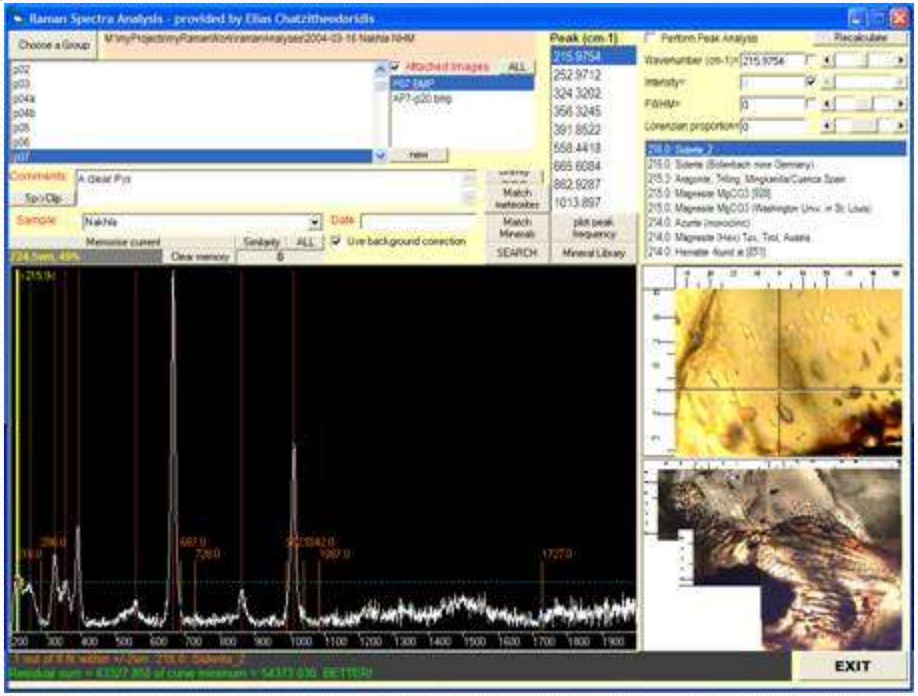
# TOF-SIMS ion map/image management system

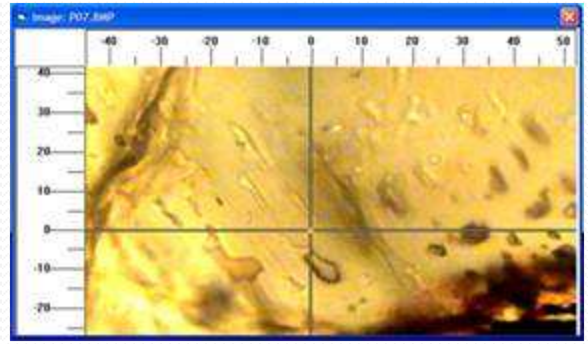


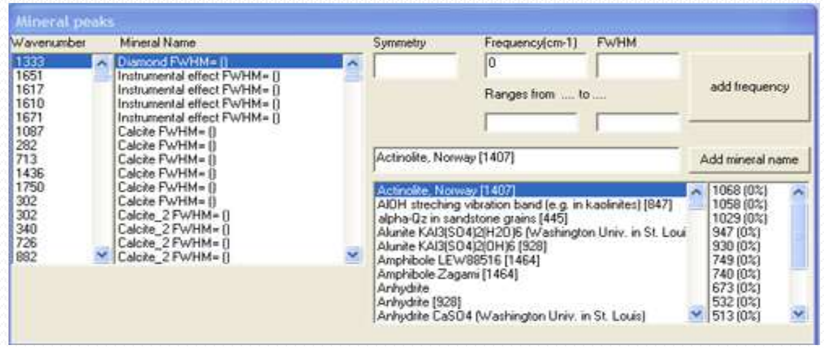
Reads the BioTOF spectra files, extracts total ion image and element or isotope images and manipulates them (based on a parser of EXCEL-like equations). Performs masking, profiles, stoichiometry, data mining, etc. Intended to assist in geochemical or mineral reaction studies, using trace elements or isotopes.

(System development based only on my own ideas and efforts)

# Raman (& other spectra) analysis system



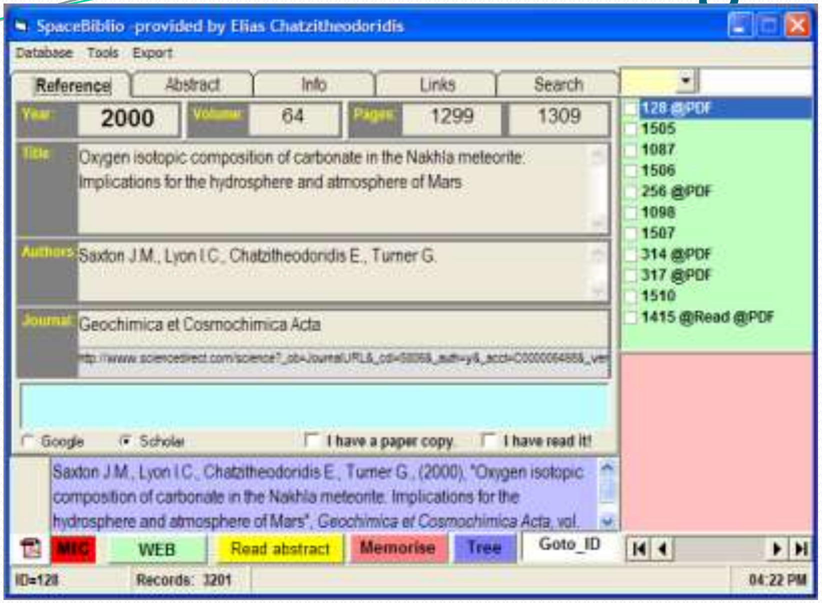



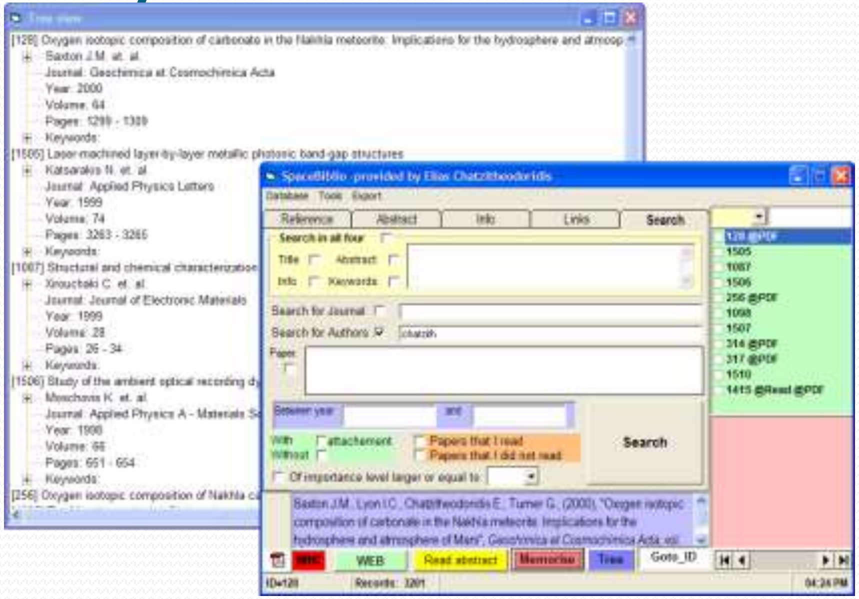



- A system which unifies the complete spectra work into a fully-interactive environment (all related data accessed from the same point: spectra, images, spectra library)
- In real-time/interactively suggests possible mineral phases
- Full search in the database of standard spectra or even between all samples to find similar phases
- Spectra manipulation for background correction, peak search, precision peak deconvolution in a semi-automated manner, peak saving, etc.
- Reads the file-spectra of Galactica Grams programme (for spectra acquisition)

**This system is developed based entirely on my own ideas and efforts**

# An automated Bibliographical system



- Background operation assisting not only in unattended reference searching (e.g. while you write a paper or search in internet) but also fully automated addition of new reference records, automated PDF file linking to record, etc.
- Single-click search in **Google** or **Scholar Google**
- Automatically reads and saves search output files produced by the **Web Of Science** database
- Full speech messaging system and voice-command control (using the Microsoft speech engine), reduces many message windows on screen and mouse clicks
- Minimum screen surface environment, and use of transparent windows to increase usability of the screen

**This system is developed based entirely on my own ideas and efforts**

# Fungi in microgravity