Applied mathematics in Firenze

A short presentation of mathematics and applications in Florence and more

Toscana Promozione
23/04/2010

Main actors

	Department of Mathematics "U. Dini" Università degli Studi di Firenze
	Department of Applied mathematics "G. Sansone" Università degli Studi di Firenze
	Industrial Innovation Through Technological Transfer Onlus

Mathematical physics group

- Main research topics
  - Mathematical modelling and industrial applications
  - Free boundary problems
  - Bio-mathematics
  - Mechanics of continuum media

I2T3 - presentation

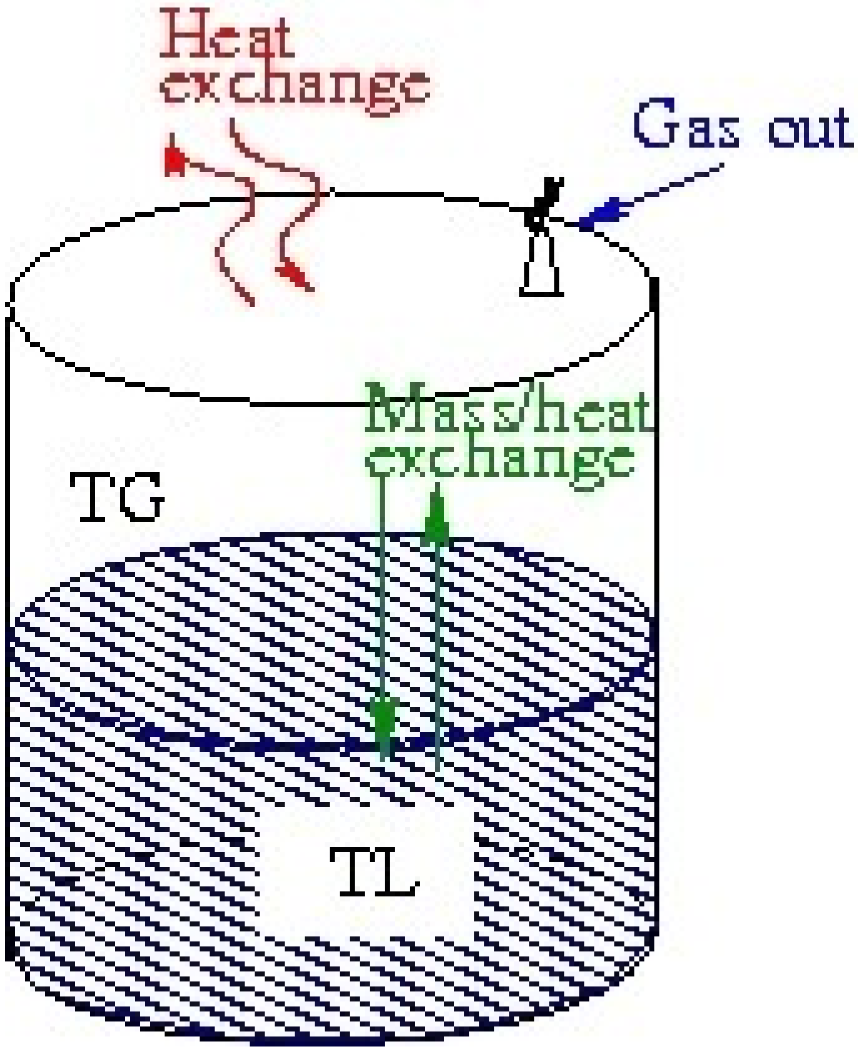
- Project management of interdisciplinary research project
- Technology transfer
- Mathematical modelling for industrial applications
- Applied ICT, infomobility, logistics etc.
- New materials (analysis, assessment and evaluation)
- Scientific analysis design
- Energy and environment
- etc.

Main applied mathematics experiences

- Thermo-fluid dynamics for industrial applications
- Transport modelling
- Modelling for electronics applications
- Fluid filtration and porous media
- Materials modelling
- Applied free boundary problems
- Other problems

BLOWDOWN

- Funded by ENI
- Rapid discharge for security reasons
- Temperature falling of 20-30 K in short time
- Need to design vessel to resist temperature and pressure stress
- Modelling is necessary to avoid cracks

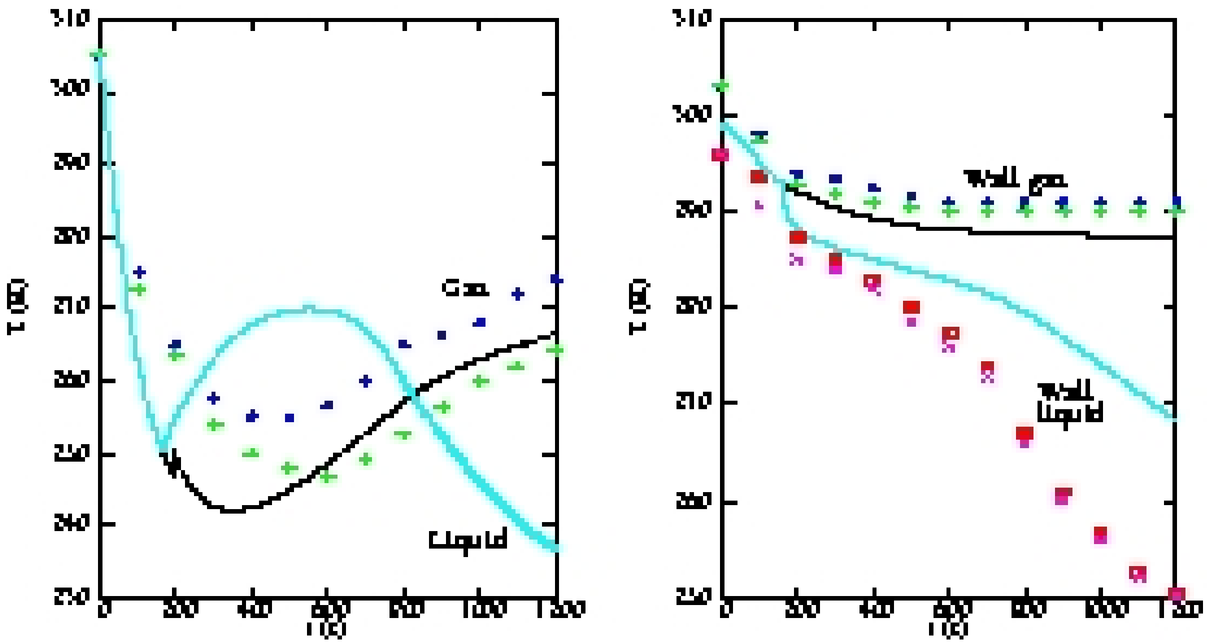


BLOWDOWN

- Mixture of hydrocarbons in gas/liquid phase in pressure vessel
- Rapid discharge, thus need to take into account phase transition during discharge. NON-EQUILIBRIUM phase change!
- All previous models assumed just one phase, or thermodynamic equilibrium between phases
- Needed to perform modelling and simulations (write a new code for simulations)

BLOWDOWN – published results

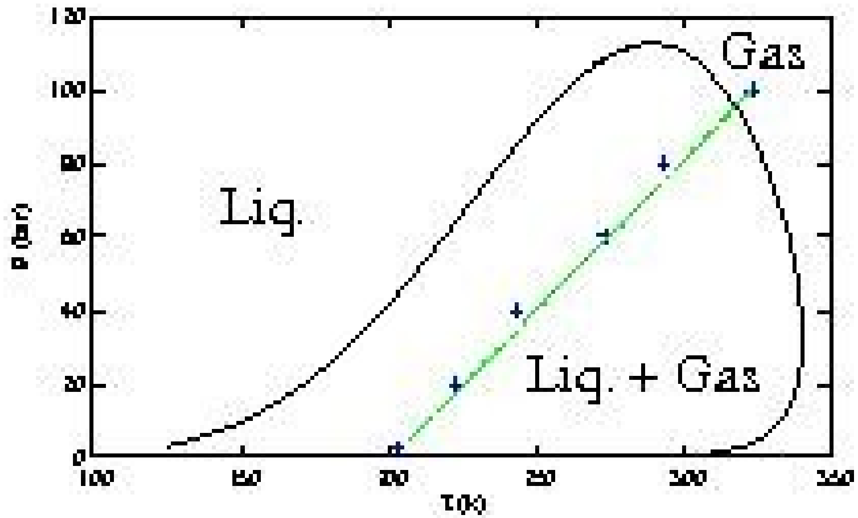
- Blowdown process



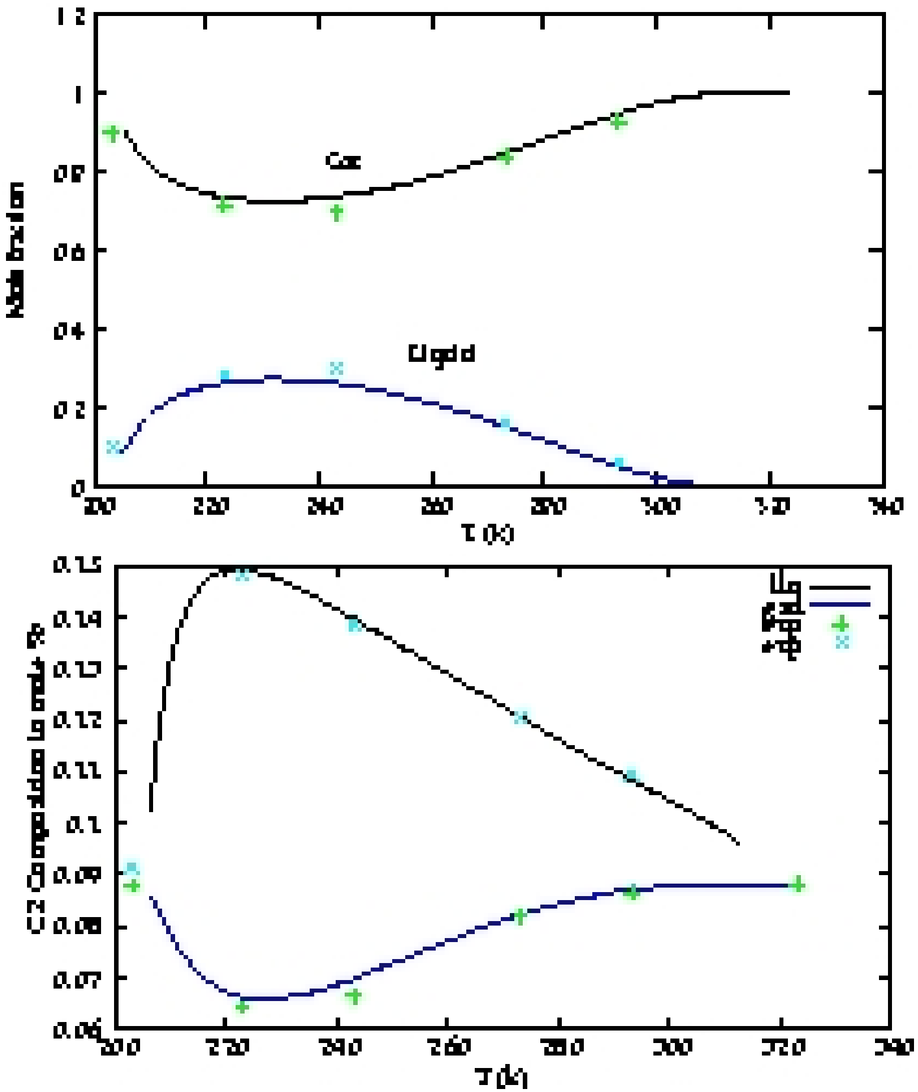
- Good agreement with experiments
- Fast/reliable and robust algorithm

Multiphase

- Funded by ENI
- Solve phase equilibria of polydisperse hydrocarbons
- Possibly large number of components
- Use fast and non-scalable algorithm



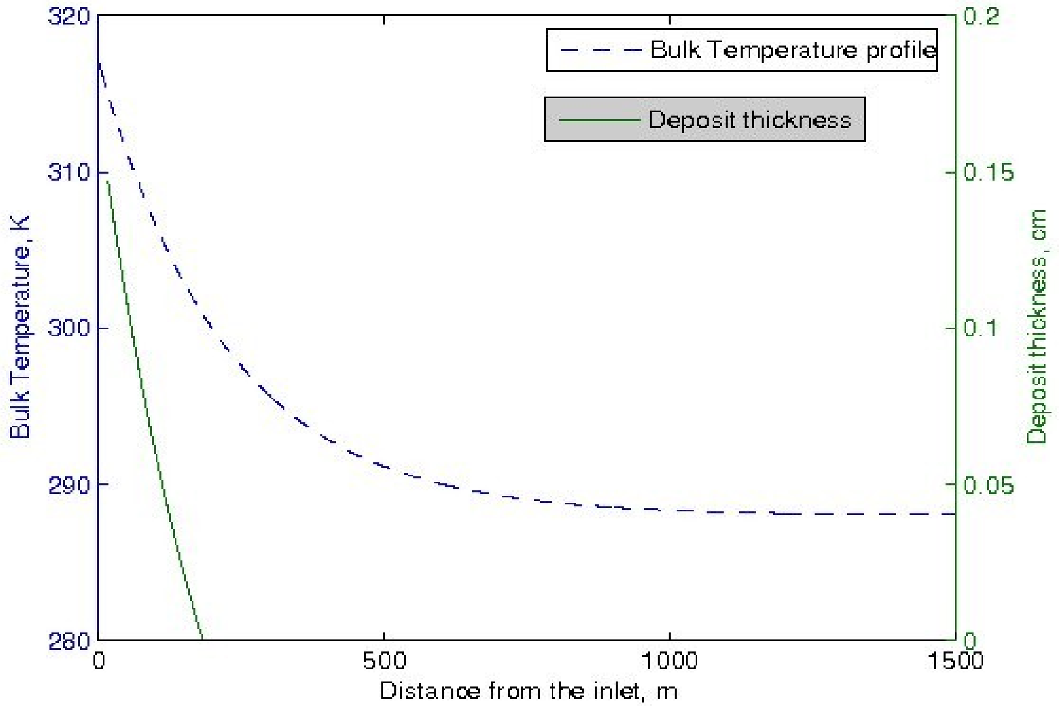
Multiphase – published results



- Excellent agreement with commercial software
- Non-scalable algorithm
- Globally stable solution reached
- Compiled as library for blowdown simulation software

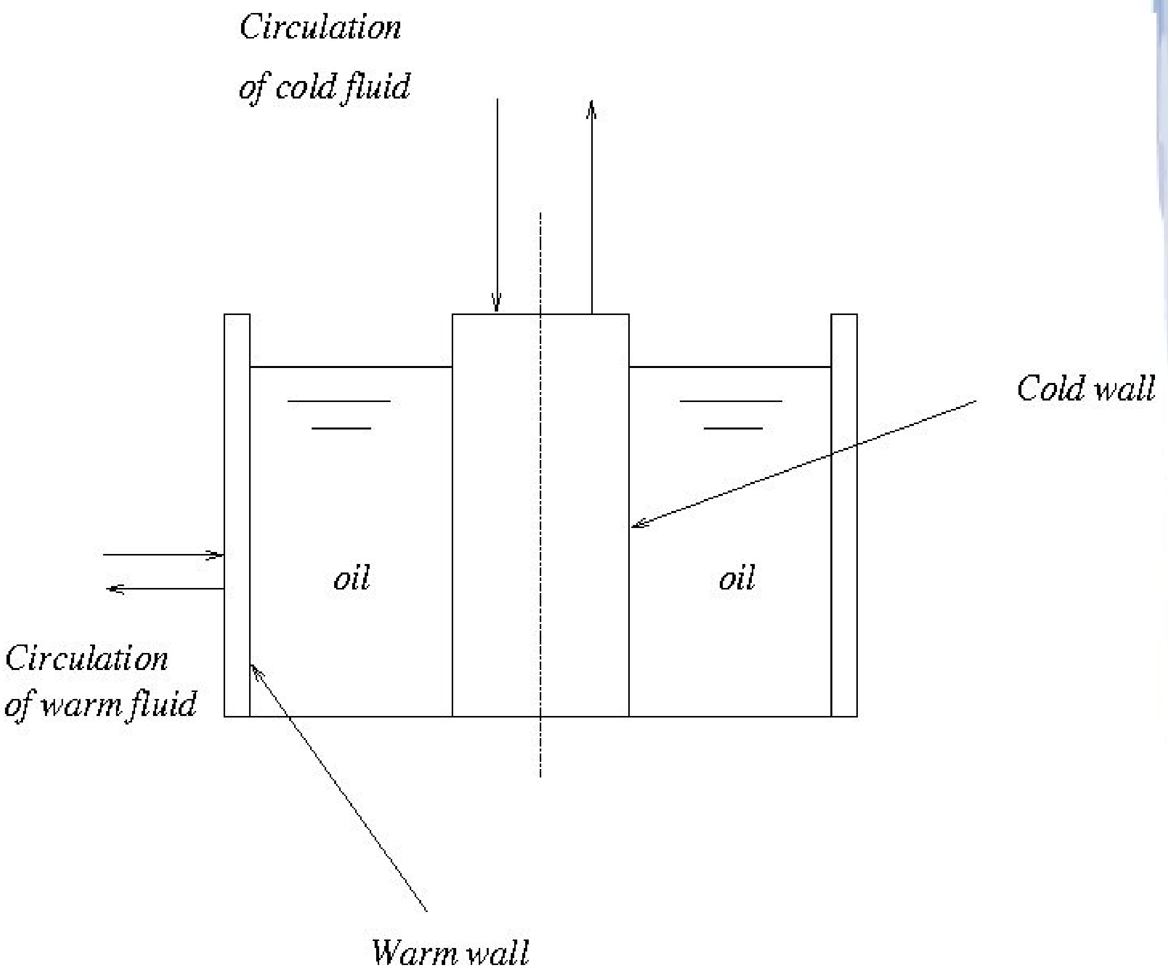
WAX – Deposition in pipelines

- Funded by ENI
- Wax deposits by Fickian diffusion
- Prediction of the amount of deposited wax



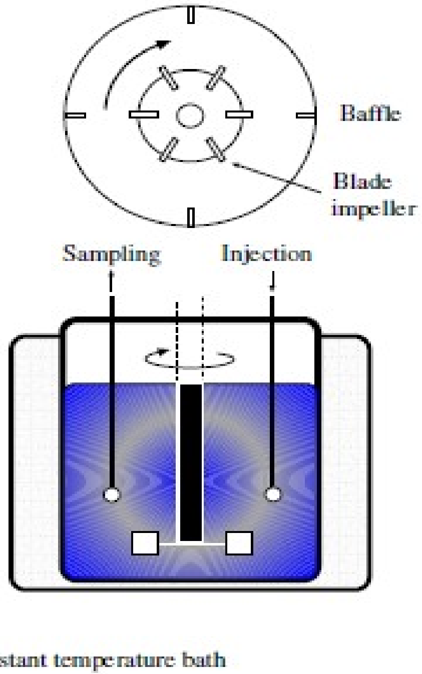
Wax – Laboratory studies

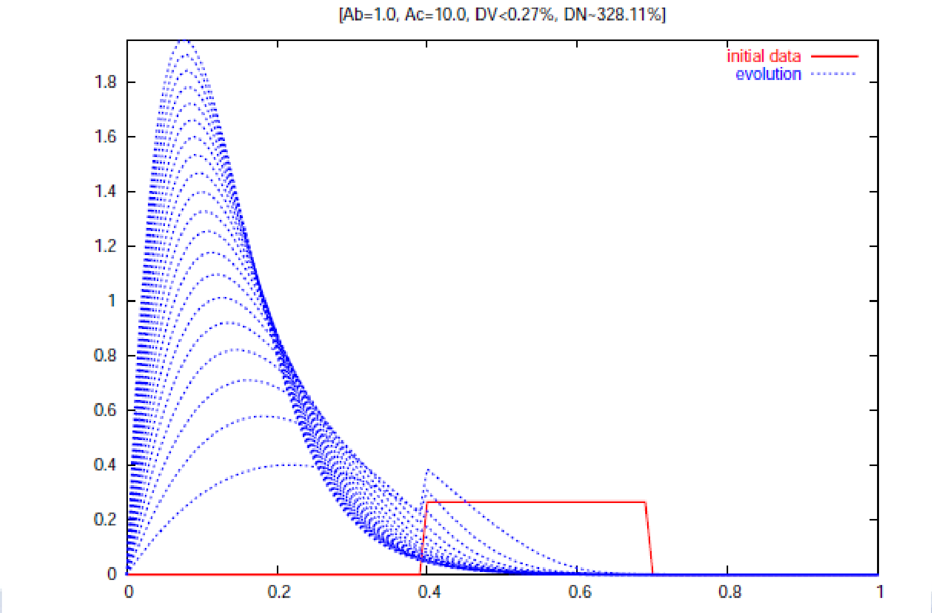
- Cold Finger
- Wax diffusivity and solubility detection
- Deposit measures
- Latent heat
- Ageing



Liquid-liquid dispersions

- Two immiscible liquids (eg. Water and oil) are mixed in some container
- Model evolution of droplets size distribution of the dispersed phase

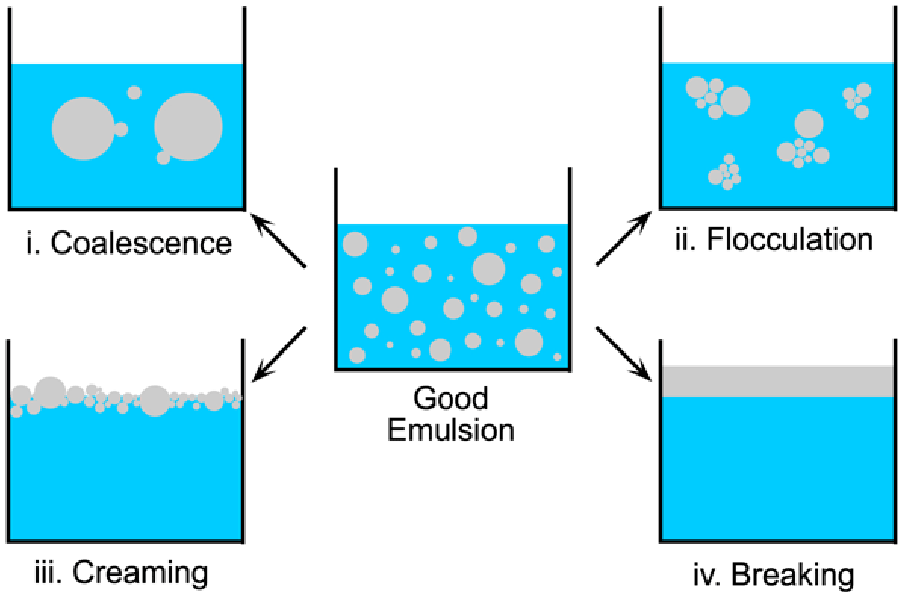




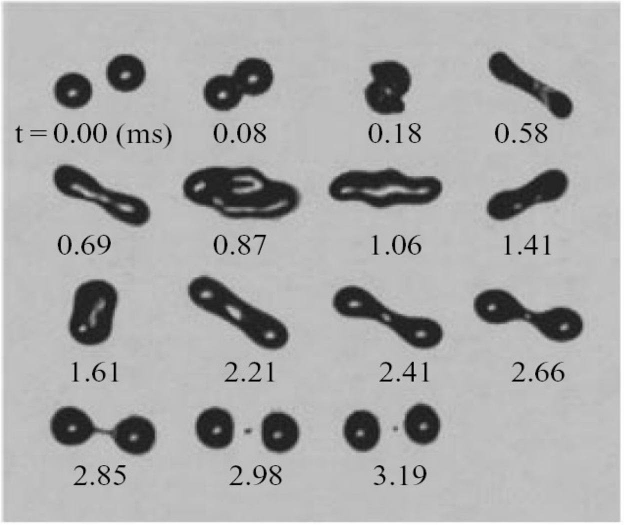
- Competing mechanisms: coalescence, breakage and scattering

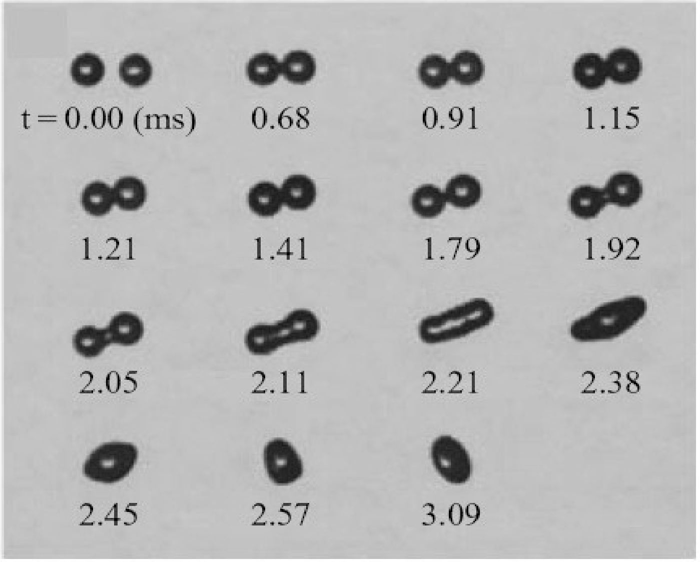
Liquid-Liquid dispersion

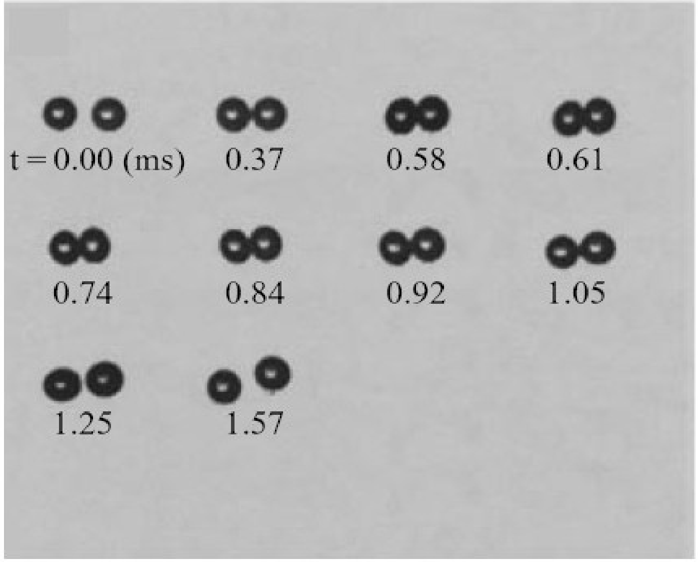
- Wide range of industrial applications
- Local behaviour of drops pourly understood
- Static instability can be a problem



Coalescence Complexity



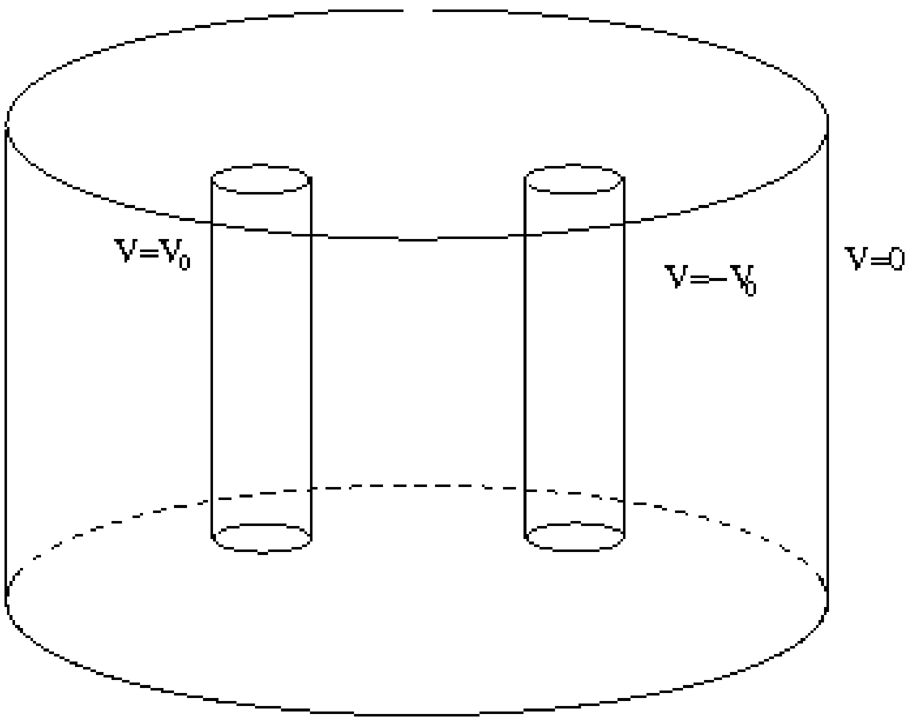




Plasma and PVD modelling

- Funded by GVS
- Modelling of glow discharge in plasma and PVD
- Typically used to metalize headlights for automotive
- Plastic substrate of projectors is alluminated, and then, covered with a thin polymer film (HMDSO)

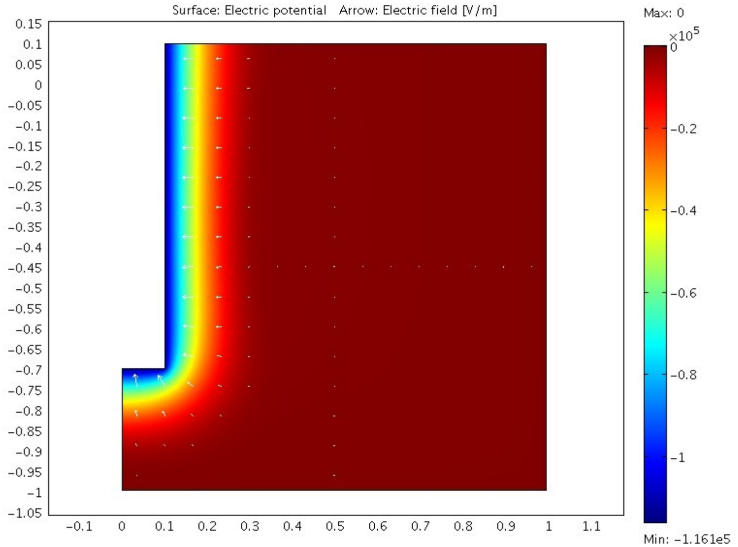
PVD modelling

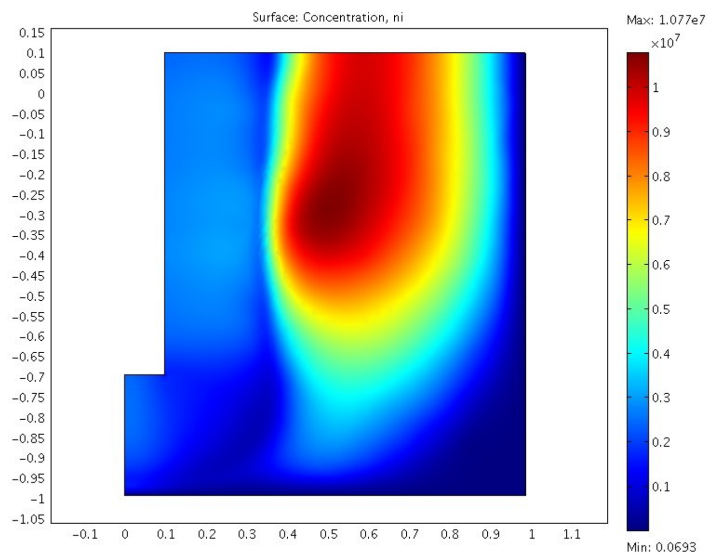


- Model simple 3D geometry
- Simplify physical conditions of atmosphere and electric discharge

- Simulate plasma conditions in different configurations of the plant (one/two electrodes, different shapes, varying distance of the electrodes and so on)

PVD – Published results

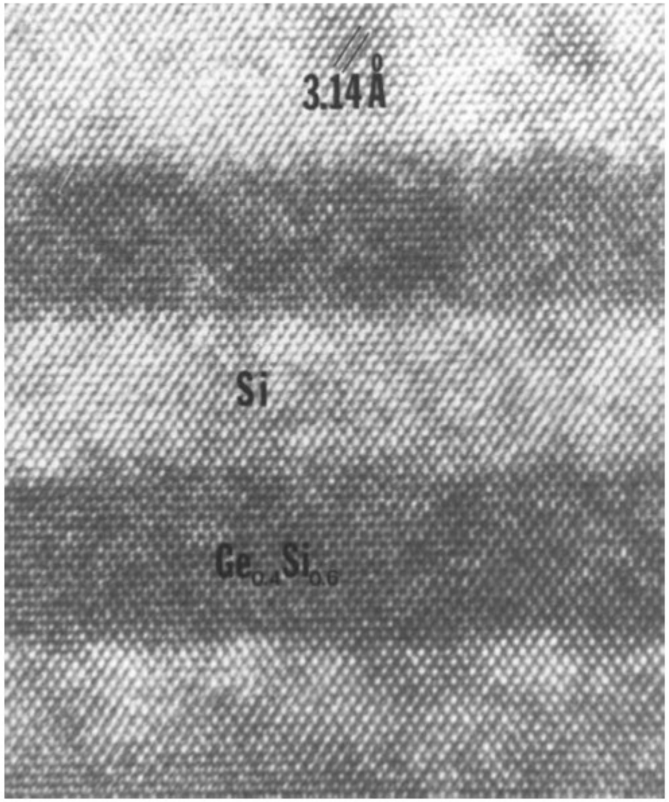




- Reliable and flexible modelling
- Based on drift-diffusion, and Poisson equation
- Allows the simulation of different geometries and plant configurations
- Useful for R&D of new plants, shape optimization etc.

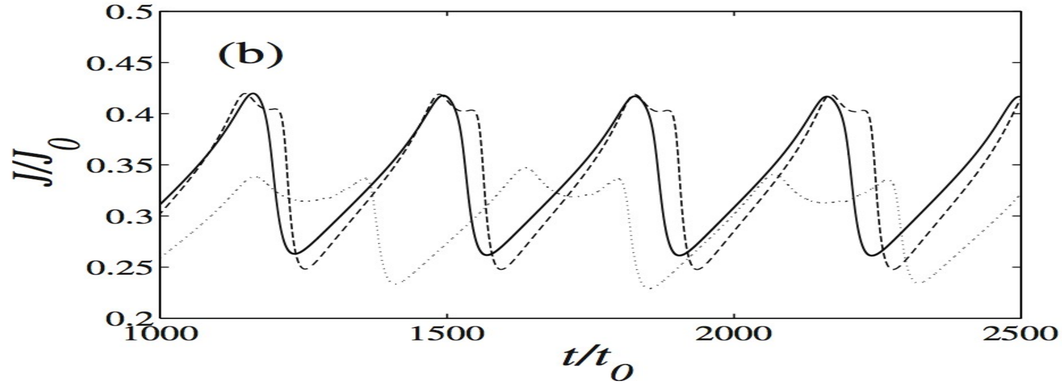
Semiconductor modelling

- Quantum-corrected fluid-dynamic models of multiband electronic devices
- Applications to:
  - Interband resonant tunneling diodes
  - Spintronic field-effect transistors
  - TeraHertz superlattice oscillator

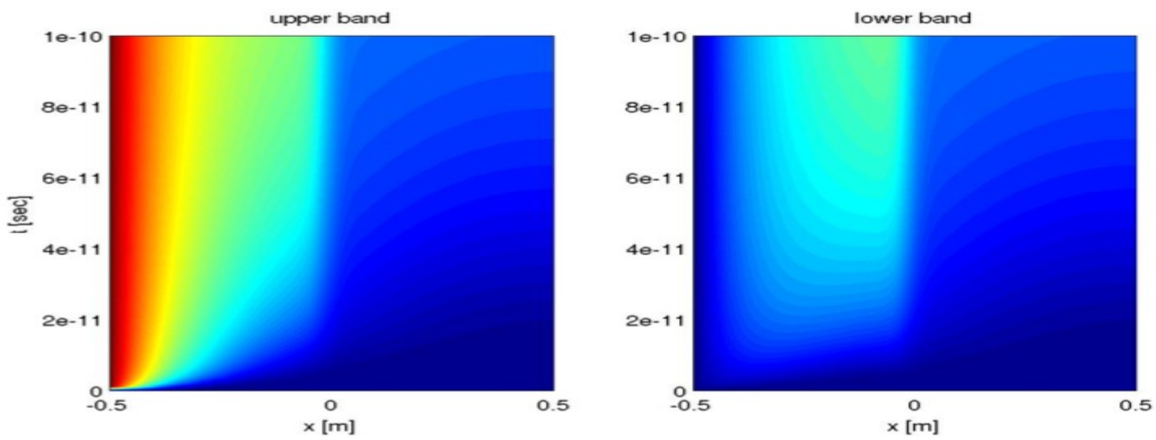


Semiconductors – results

- Simulated behavior of a SL oscillator



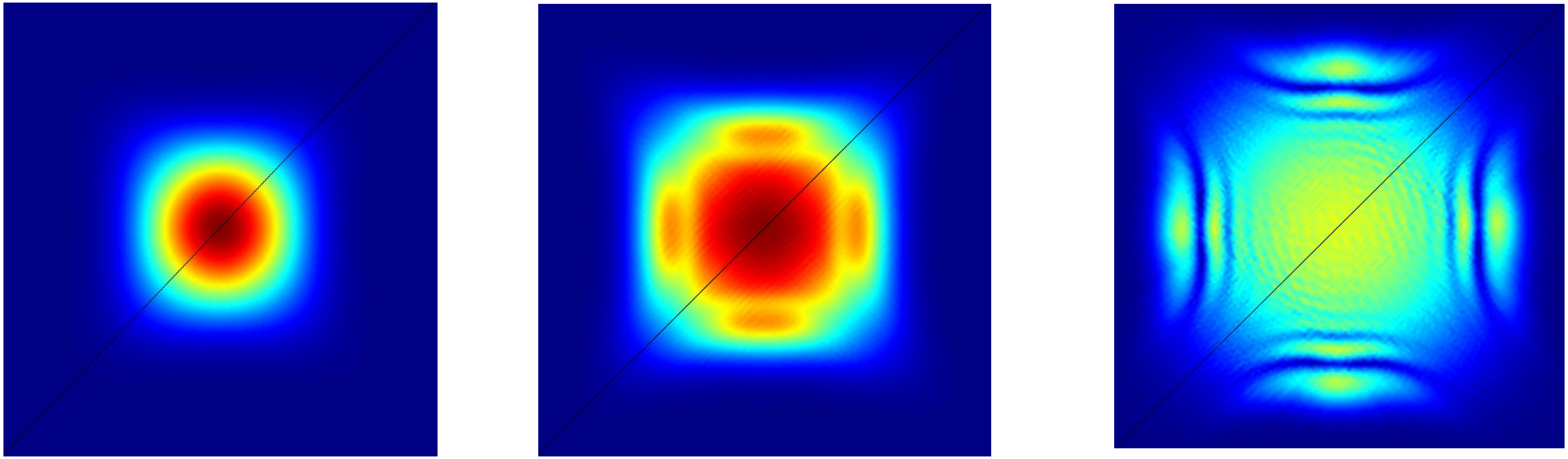
- Simulated behavior of a interband device



- Experimental agreement

Noise in optical fibers

- Funded by CNIT
- Issue: modelling nonlinear noise-signal interaction in telecommunication optical fibers
- Result: deterministic equations for the statistics of the output signal+noise



Fluid filtration and porous media

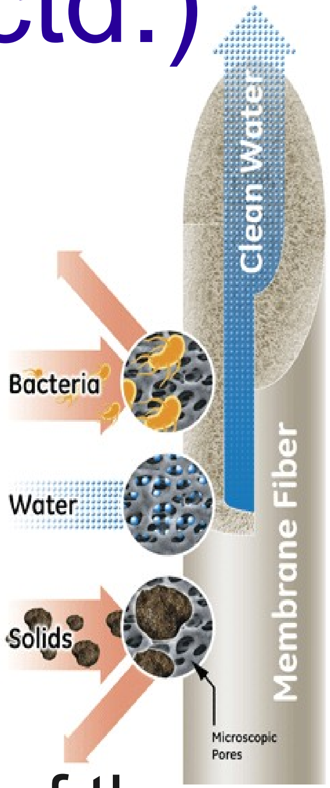
- Many applications
  - Hydrologic models (e.g. Pollutants diffusions, landfills modelling, water reservoir modelling and so on)
  - Geothermal modelling (wells and reservoir modelling)
  - Oil production
  - Industrial applications (evapotranspiration, filtration, comfort etc.)

Waste waters filtration model

- Many projects; lately:
  - *GOFIM* (2009 - funded by FRI): application of a filtration model to an industrial plant for drinking water. The plant is made by *GAC (granular avctivated carbons)* filters joint with an *Ultra Filtration* filtering system based on immerged hollow fibers modules.
  - *PURIFAST* (2009 – 2012 funded by EU *Life*+): application of modelling techniques to pilot and pre-industrial plants based on membrane filters (Hollow Fibers and Multi-Bore) to clean industrial and municipal waste waters.

Membrane filtering models (ctd.)

- **Main problem in membrane filtering systems**: due to the pressure difference the particles to be filtered eventually soil the membrane (adsoprtion and/or pores clogging). This process (the s.c. *fouling*) increases the pressure difference (= energy cost).

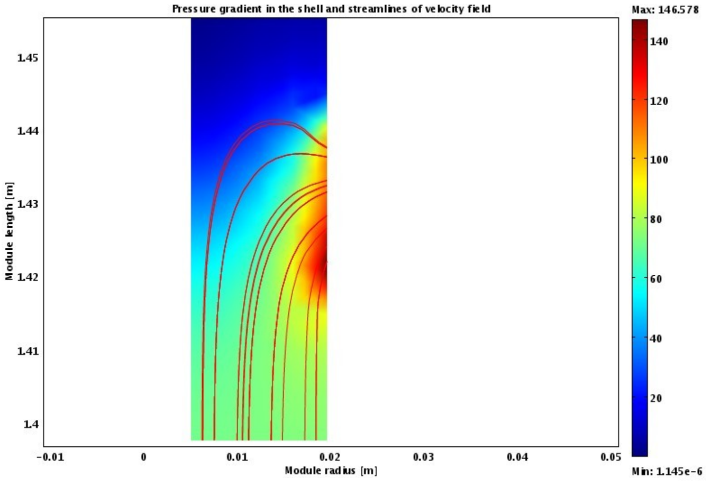


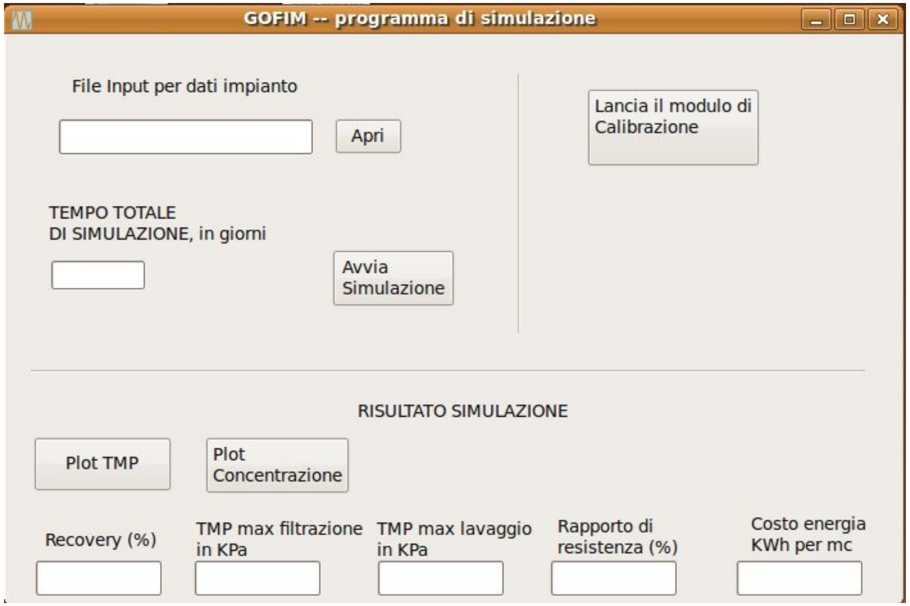
- **Modelling task**:
  - describing filtration process by the coupling of the hydrodynamic problem with the transport/adsorption of particles.
  - optimizing product and process parameters (on the basis of simulations)

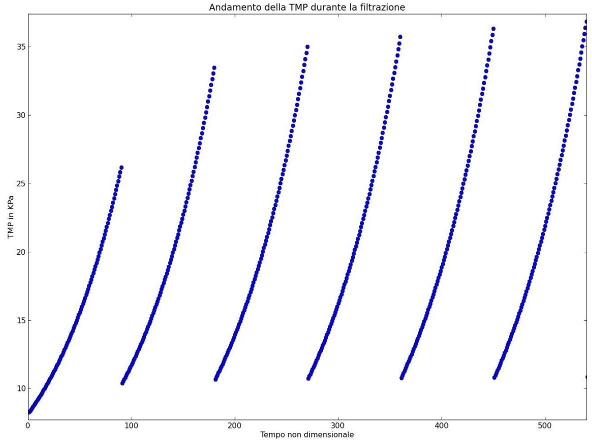
Membrane filtering models (ctd.)

Several models describing:

- The single cycle of filtration and back wash step (1D or 2D models).
- The whole step of filtration (typical some days), made by several cycles







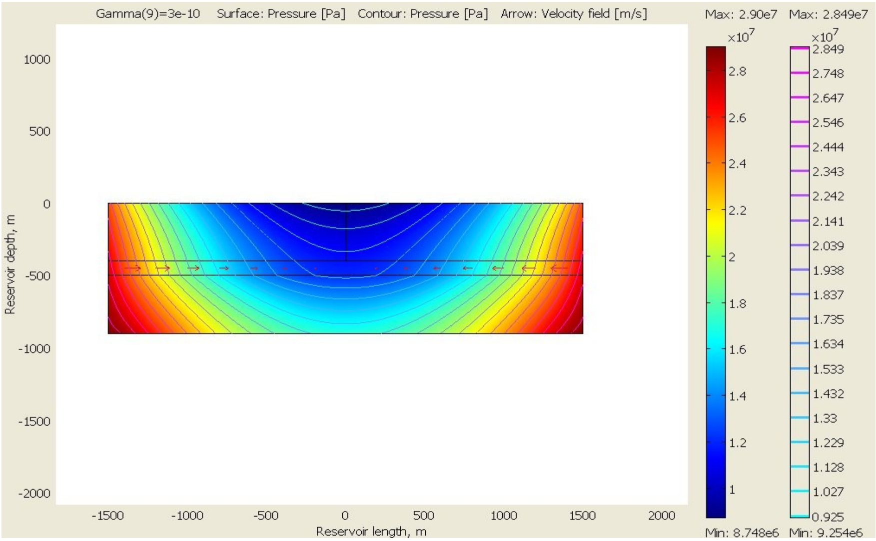
Hydrological and Hydrogeological modelling

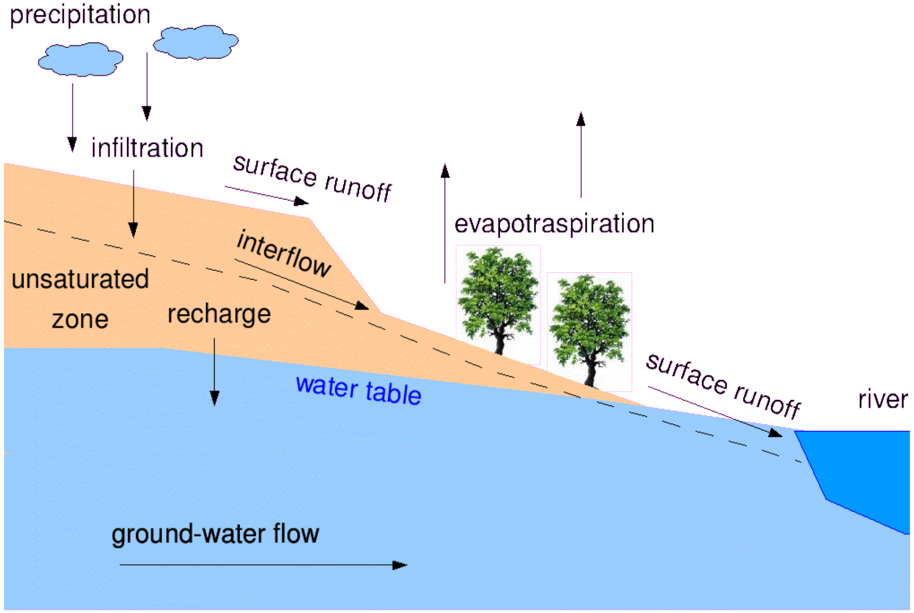
- Many projects; lately:
  - MAC-GEO (2008 – 2010, funded by Tuscan Regional government): modelling geothermal reservoirs.
  - SID&GRID (2010 – 2013, funded by Tuscan Regional government): modelling the whole system of surface and subsurface waters.

Hydrological and Hydrogeological modelling (ctd.)

Several topics:

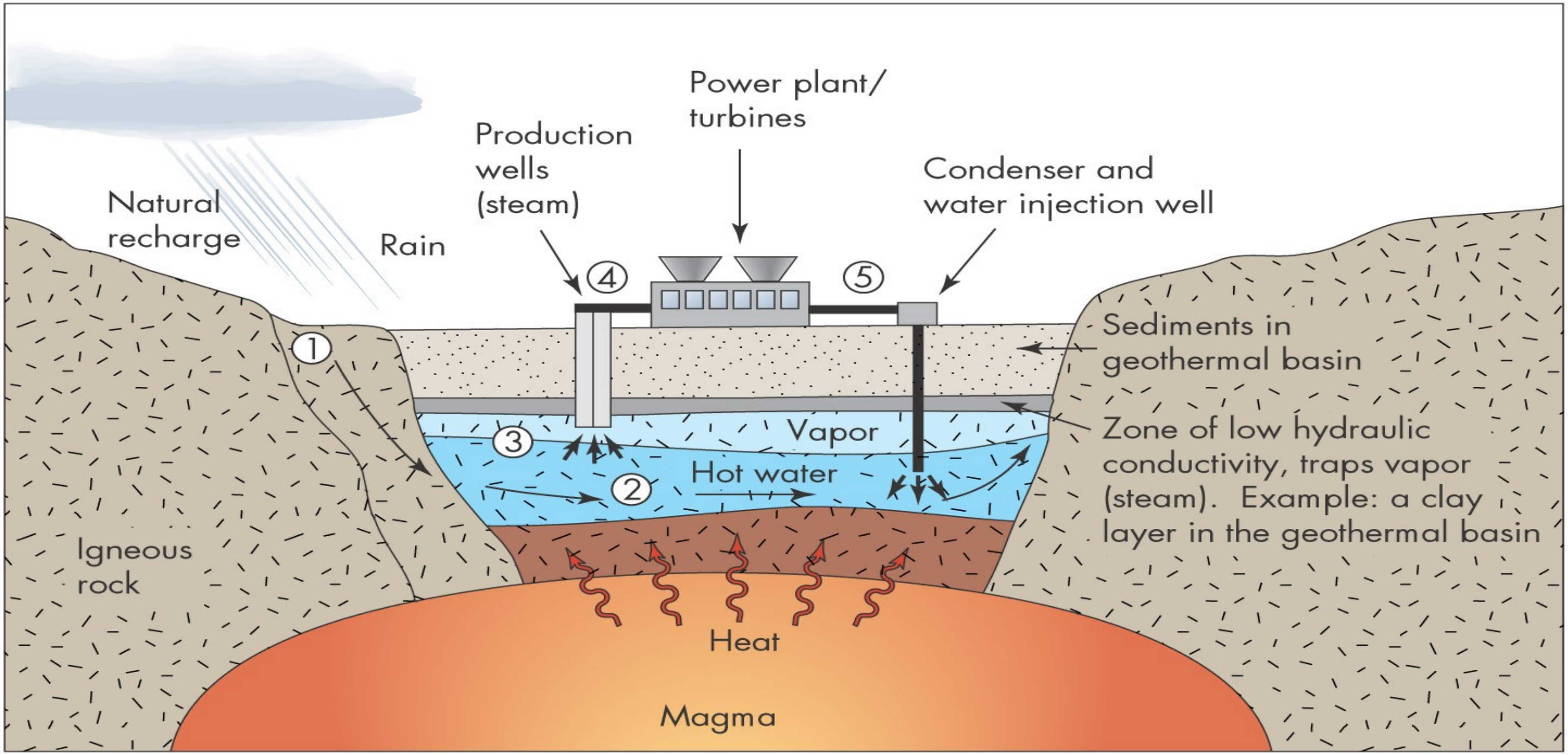
- Geothermal systems: thermodynamics (phase equilibria), modelling withdrawal zone and well productivity, etc.





- Shallow and groundwaters: response to climate inputs (evapotranspiration, infiltration, runoff), unsaturated zone flow, coupling with streams and lakes, pollutant transport,..

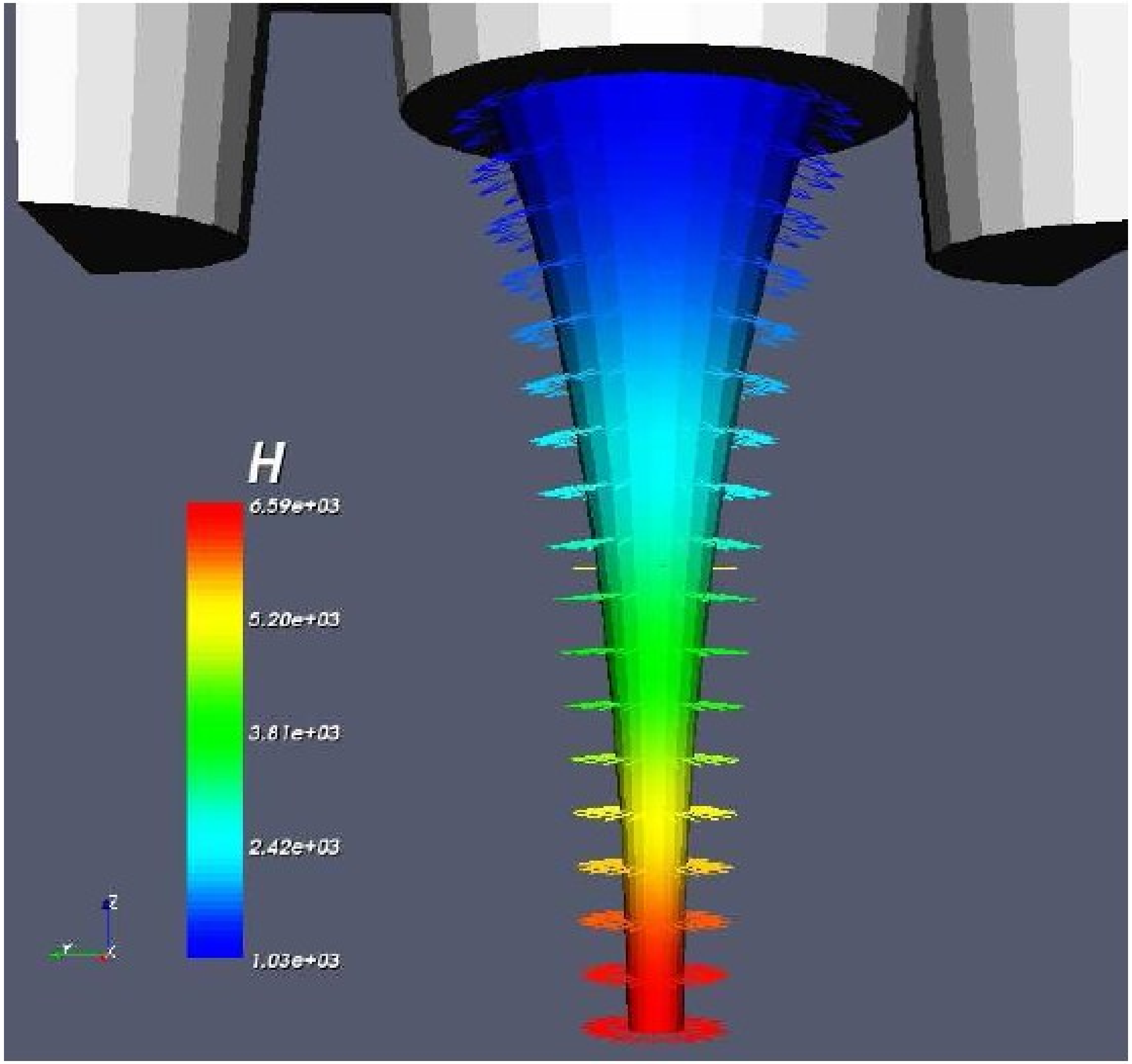
Geothermal Reservoir Modelling



→ Direction of water flow

1. Natural recharge of water from rain
2. Hot water produced by earth processes
3. Steam to production well
4. Steam to turbines to produce electricity
5. Water is injected back into ground

Modelling of Glass Fibers Manufacturing



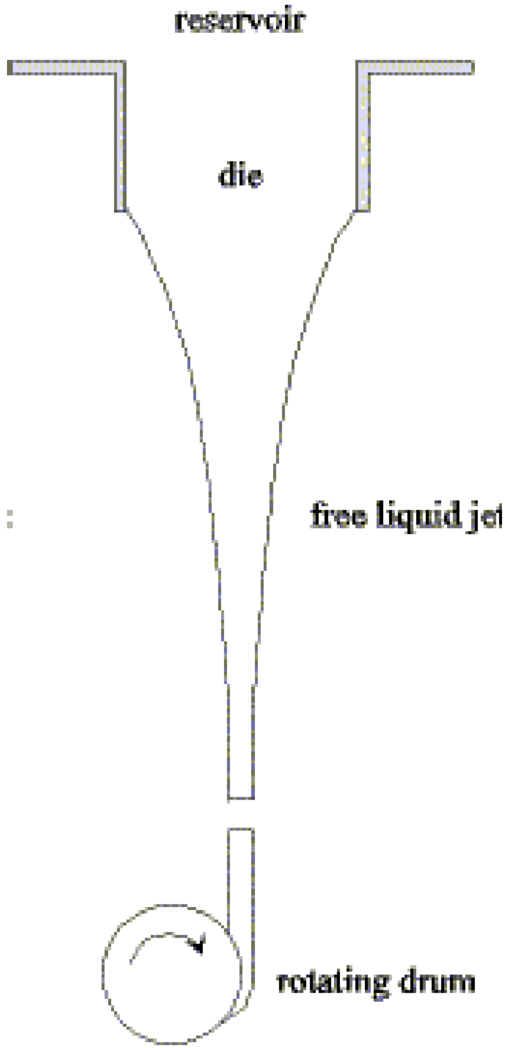
Process Stages:

1. Slow flow in the die,

2. Jet formation under rapid cooling,

3. Terminal fiber profile

Modelling of Glass Fibers Manufacturing



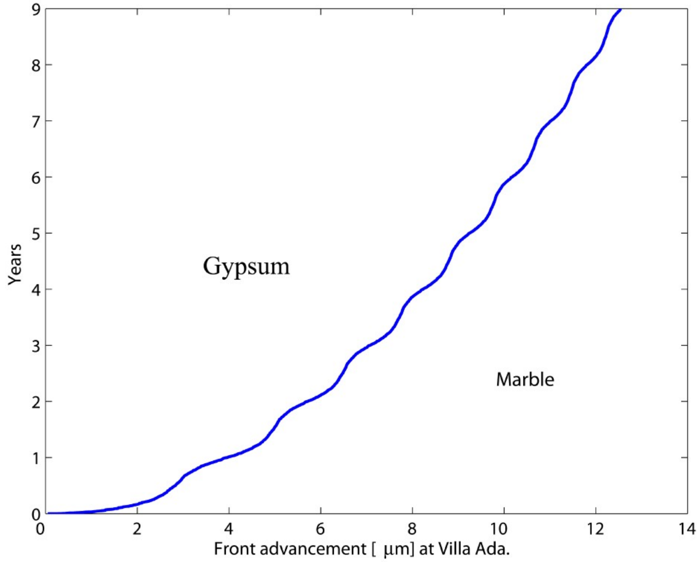
- Velocity in the die ~ 1mm/s
- Terminal velocity ~ 30m/s
- Fast cooling of the free jet change dramatically all physical parameters
- Tasks: to model all process stages

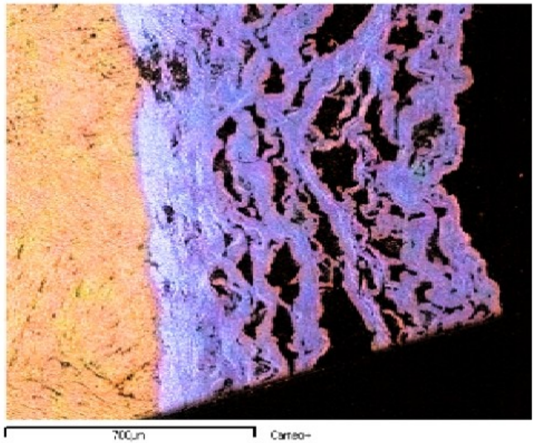
Marble deterioration

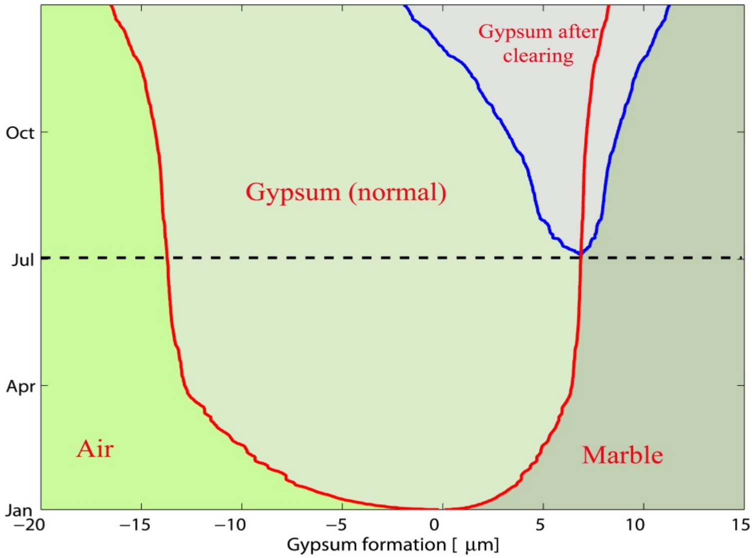
- Funded by ICR
- Marble deteriorates due to a chemical reaction induced by atmospheric agents (temperature, humidity etc.)
- Need to model evolution of front between marble and external gypsum

Marble deterioration

- Modelling allows to foresee evolution, with and without restoration procedure

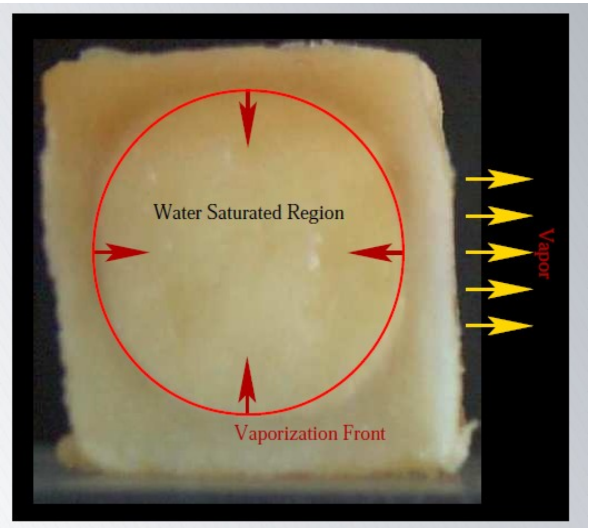


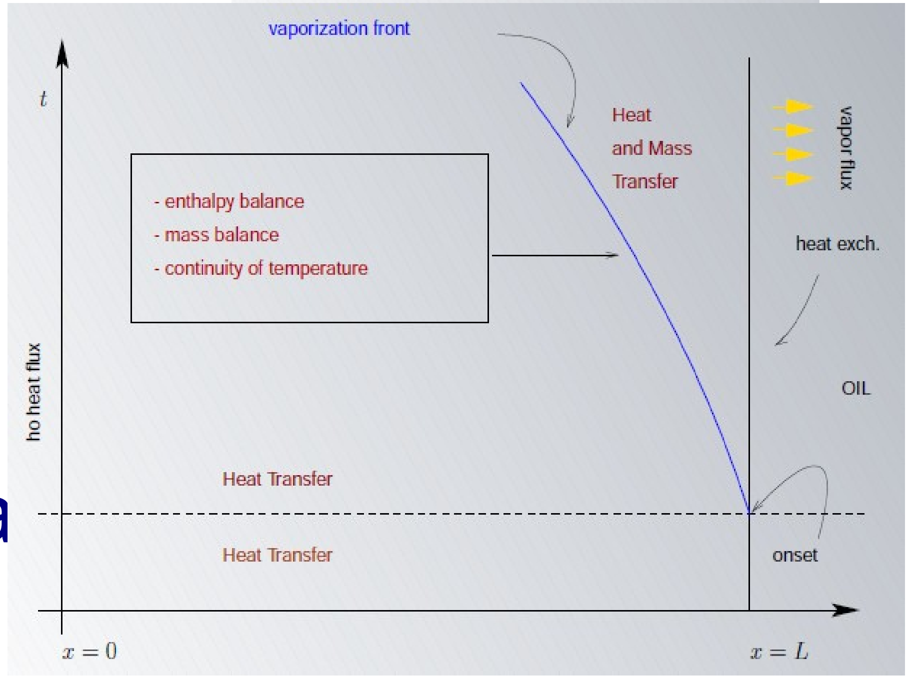




Free boundary and food industry

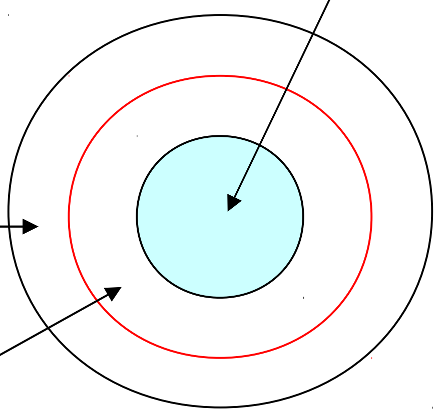
- Crust formation in the frying chip is a free boundary problem
- Front between crust and water saturated region evolves as chip fryes
- Modelling allows right setting of cooking parameters (time, oil temperature etc.) to get a good chip





Free boundary and food industry

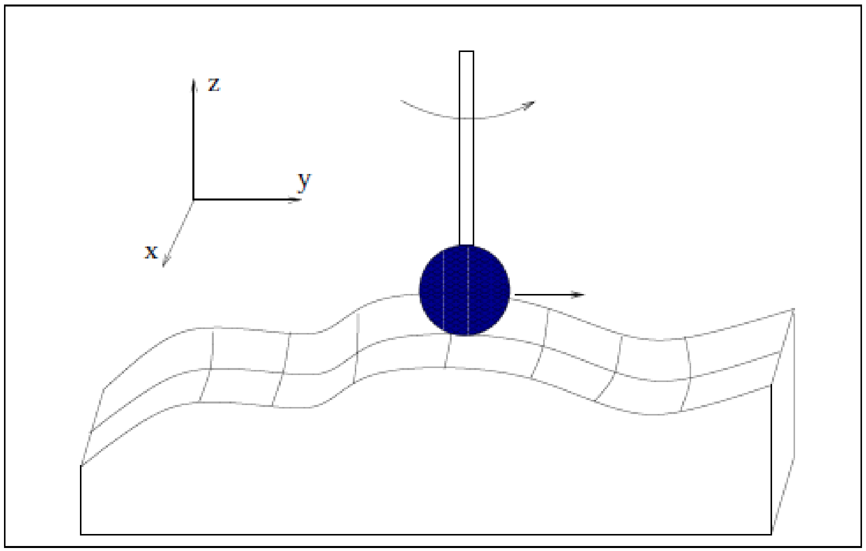
- Similar problem for spaghetti cooking
- Model cooking process as moving free boundary

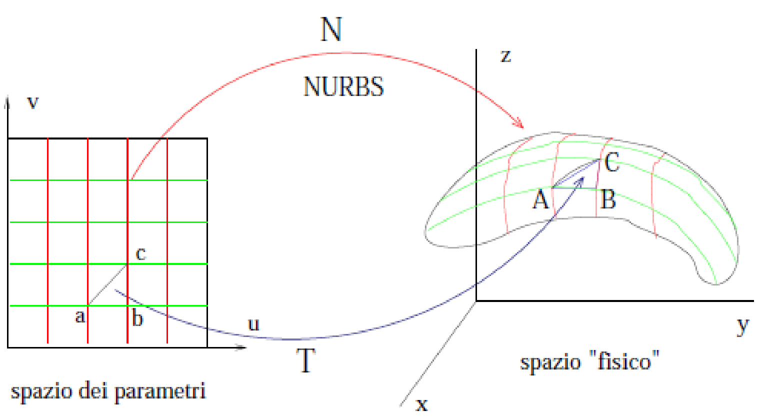


A two-stage process:

- **water penetration**
- **gelatinization**

AUTON, from CAD to CAM





- Model motion of cutting head on the surface
- Replace usual NURBS surface reconstruction, from CAD, with a surface of triangles
- Reduce offset problem (ie, where to position head)

Neural Networks

Last most relevant projects: SSAMM (funded by Foundation for Research and Innovation of Florence University), ARPAT (funded by ARPAT), Montevarchi (funded by Municipality of Montevarchi)

Application:

- Traffic forecasting: flow forecast, travel time forecast, speed forecast
- Emission forecasting
- Best price prediction in public contracts

Transport Management

Most relevant projects: Fortezza (funded by Municipality of Florence, Metromob (founded by Municipality of Florence)

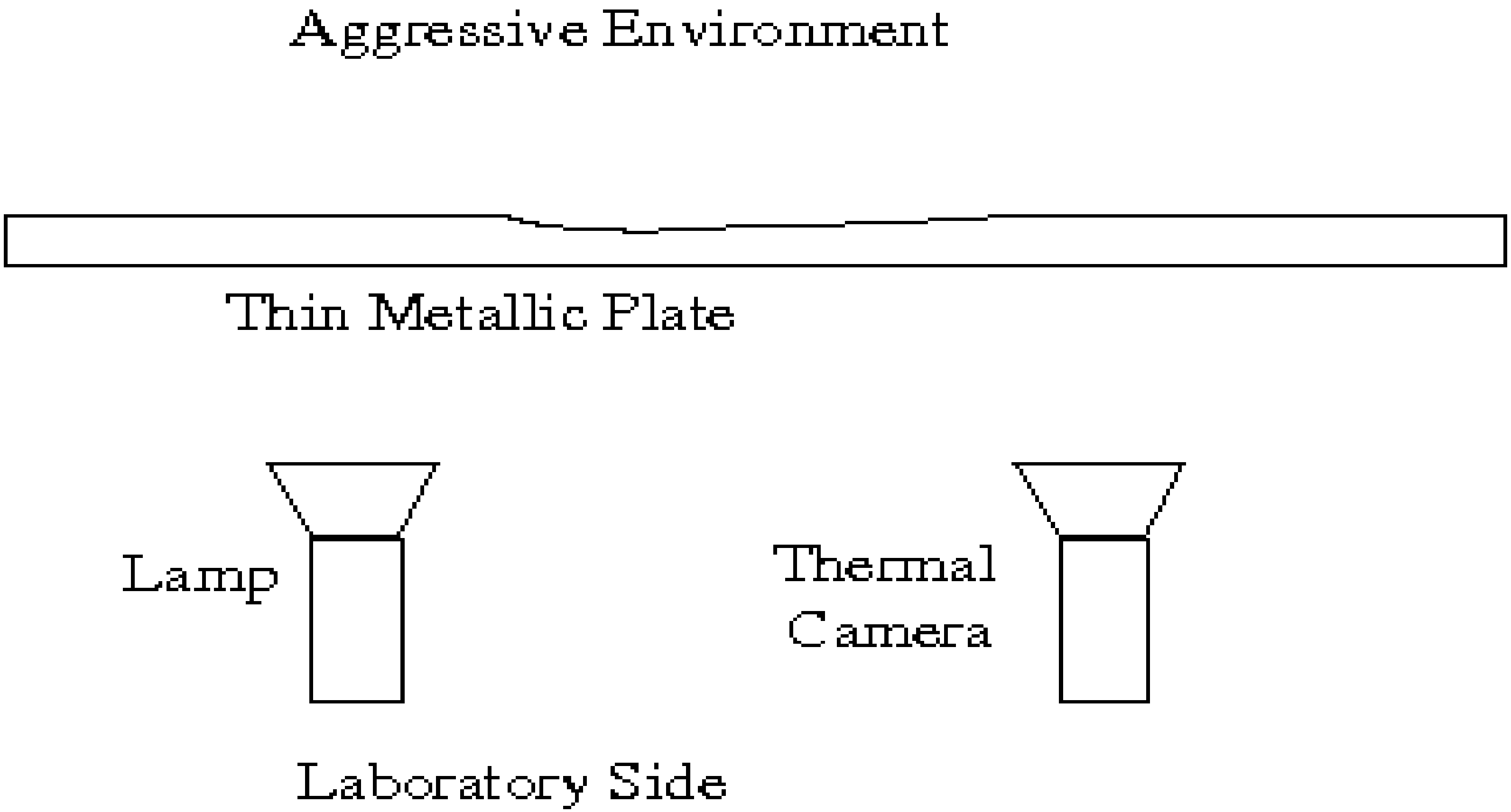
Application:

Traffic impact simulation of the new parking area near Fortezza da Basso

Ticket price optimization for public transport

Inverse Problems

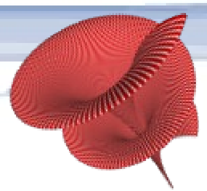
- Active Infrared Thermography for non destructive evaluation of corrosion damages on thin metallic slabs.



Other topics

- Biological modelling
  - Tumour growth dynamics
  - Bones growth dynamics
- Sociological modelling and criminality
- Industrial modelling
  - Polymer formation
  - Sedimentation
  - Fluid dynamics of complex fluids
  - Rheology
  - Composite materials
- etc

Our applied mathematics network



- Industrial partners and public bodies
  - ENI spa, ENEL spa, Galileo Vacuum Systems srl, TNT group, Publiacqua spa, Gida spa, ATAF, Comune di Firenze, Comune di Montevarchi, ATAF, NT Tecnotessile, AUTON (aggiungere filtri)
- Applied mathematics networks
  - SIMAI (member of DB), ICIAM, ECMI, EMS

Our applied mathematics network

- Italian institutes
  - MOX Politecnico di Milano, Politecnico di Torino, Università di Catania, CRS4, Università di Bologna, Università di Pavia, Scuola Normale di Pisa, Scuola Superiore Sant'Anna, IAC-CNR, IASI-CNR, Ist. Europeo Oncologico etc.
- EU and others
  - ITWM, UCM Madrid, Carlos III Madrid, Université Lyon 1, King's College London, Texas A&M University, Universidad de Oviedo, Universidad de Cadiz, OCIAM etc.

...and more work

- Hydrogen fuel cells for public transport
- Operative research and global optimization
- Neural networks and artificial intelligence
- Computer science and software engineering
- Materials analysis and new materials
- Sensors technology, ICT-Wireless etc.
- Robotics and mechatronics
- Mechanical engineering and prototyping
- Process optimization and logistics
- MIND Project

MIND project

- Open agreements with laboratories and departments from Università di Firenze and CNR
- Rapid access to laboratories and highly specialized competences
- Projects can reduce to small size, such as single analysis
- I2T3 works as front-office

Contacts

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