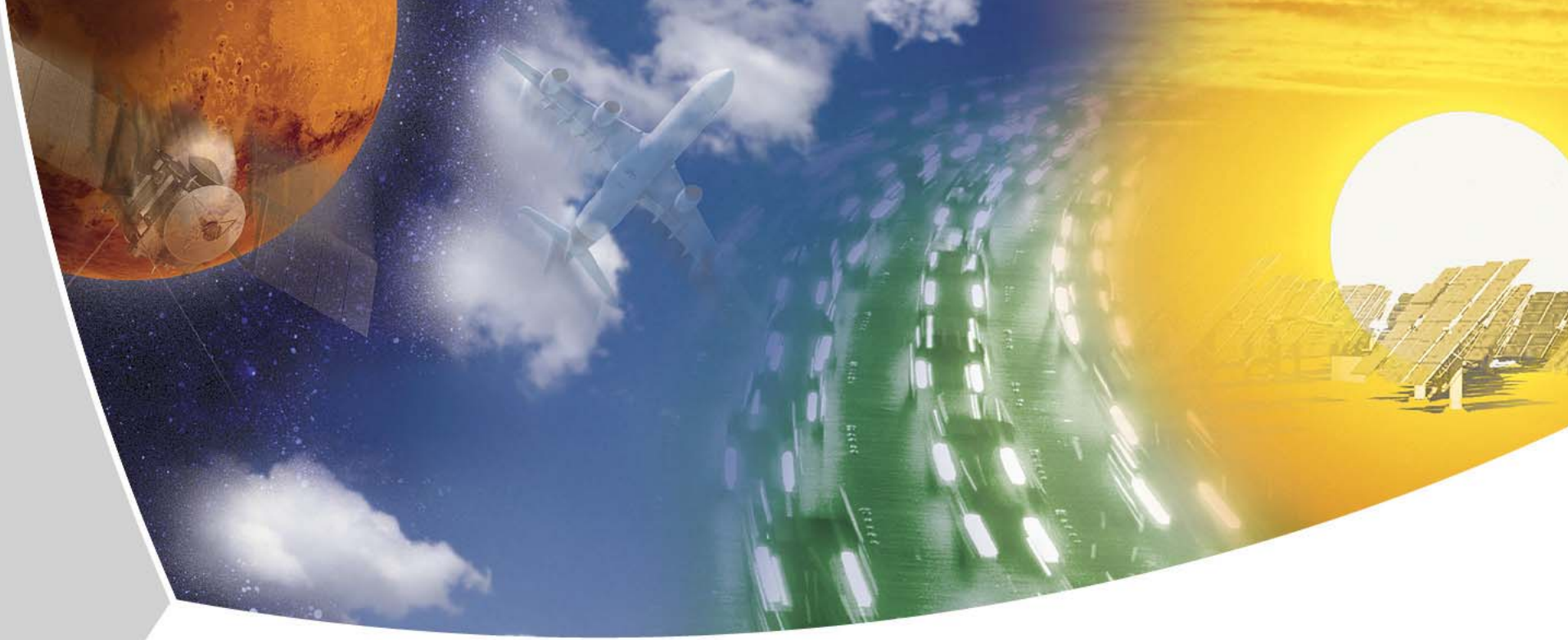

Electromagnetic Levitation: Technical and Scientific Aspects

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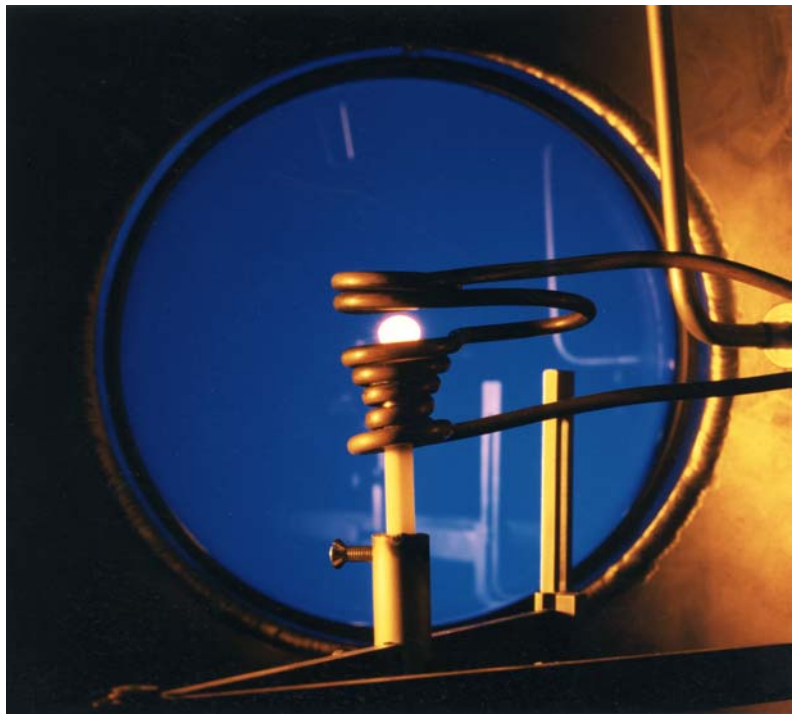
in der Helmholtz-Gemeinschaft

Meeting on Levitation Techniques, Bilbao, 10.10.2007

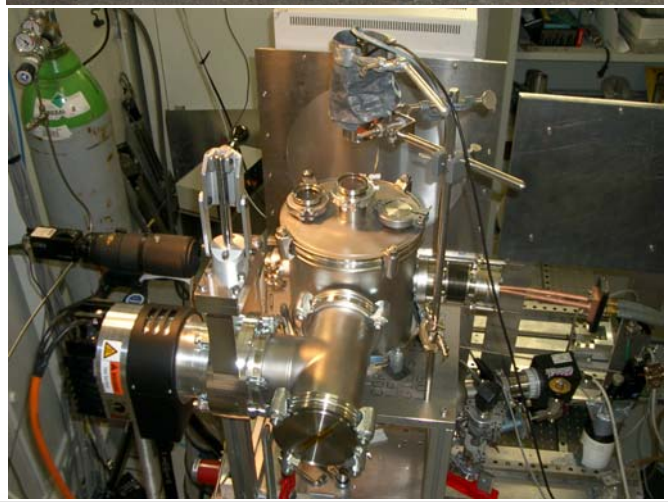
Outline

- **Introduction**
  - Electromagnetic Levitation
- **Scientific Results**
  - XAS
  - XRD
  - ND
- **Technical Aspects**
  - accommodation
  - interfaces
- **Summary**



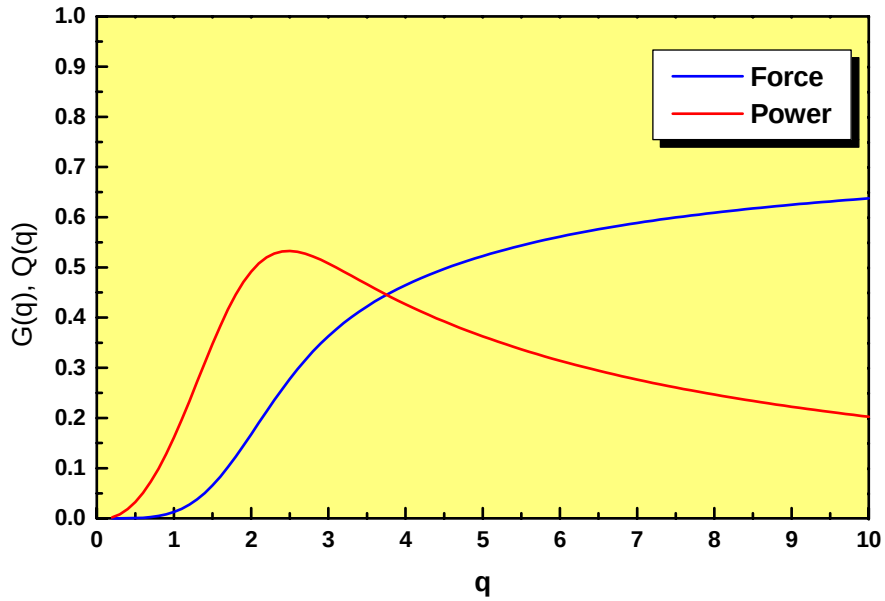
Introduction

- **Combination of levitation with synchrotron and neutron sources**
  - ⇒ Structure of undercooled melt accessible
- **Research topics**
  - Link to macroscopic quantities density, viscosity
  - Chemical/structural short range order
  - Atomic dynamics
- **Research tools**
  - Energy or angle dispersive x-ray diffraction (XRD)
  - X-ray absorption spectroscopy (EXAFS)
  - (quasi-)elastic neutron scattering



Electromagnetic Levitation

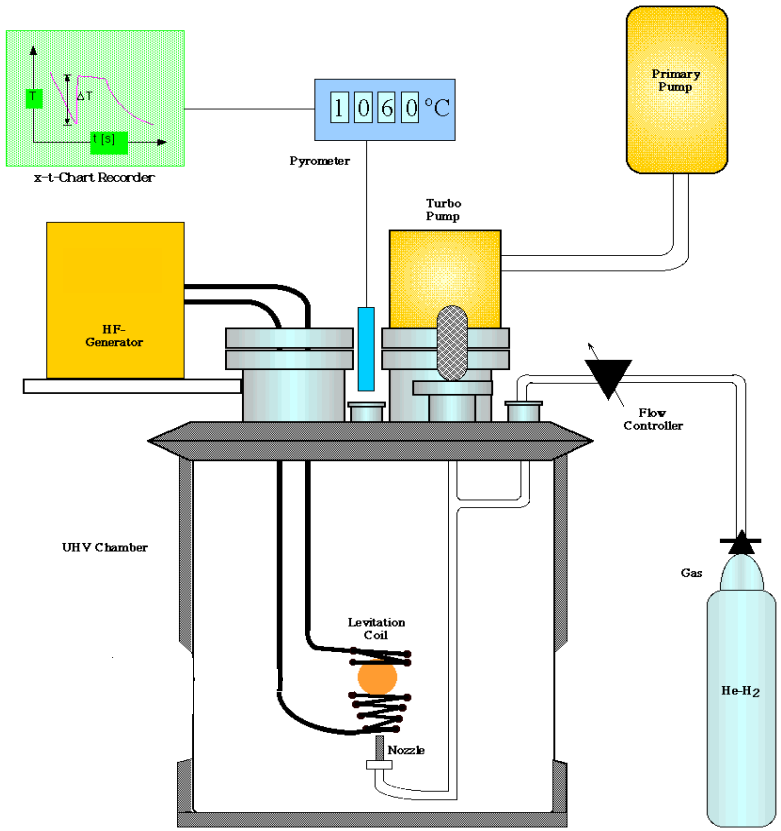
- Containerless processing of liquid metals
  - No scattering from crucible
  - No crucible reactions
  - High temperatures
  - undercooling
- Inert atmosphere
  - Helium or Argon
- Bulk samples (1g)
  - Nearly spherical
  - Translational oscillations (≈ 5 Hz)
  - Surface oscillations (≈ 30 Hz)
- Non-contact-diagnostics
  - Pyrometry
  - Videometry

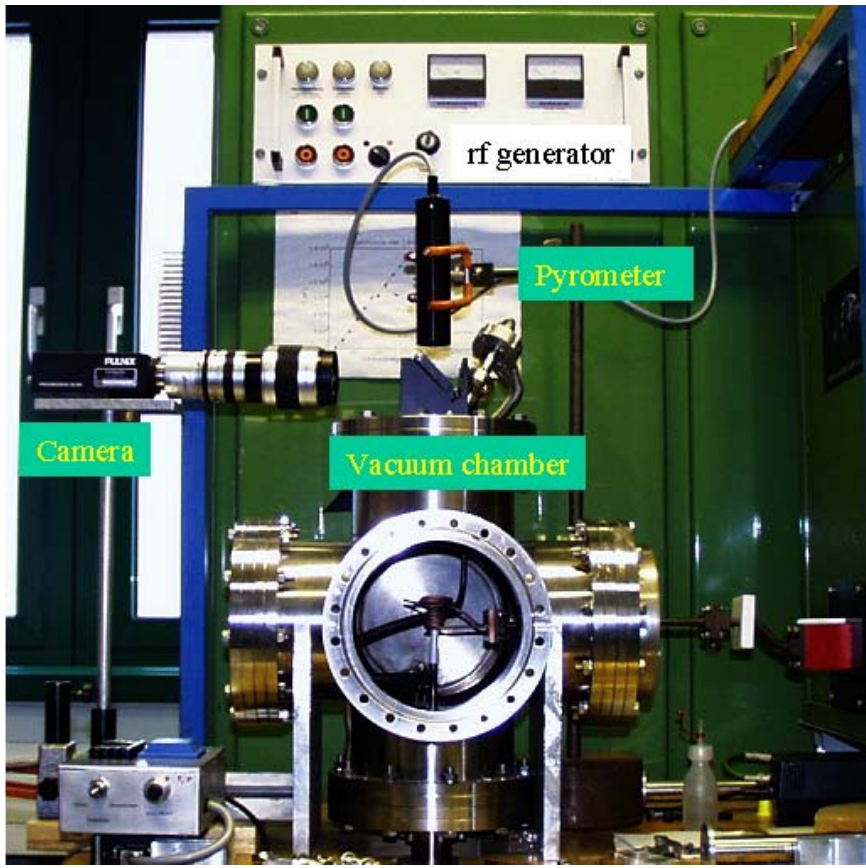


$$F = \frac{\nabla B^2}{2\mu_0} V\, G(R_0/\delta)$$

$$P = \frac{B^2}{2\mu_0} V \omega\, Q(R_0/\delta)$$

Electromagnetic Levitation



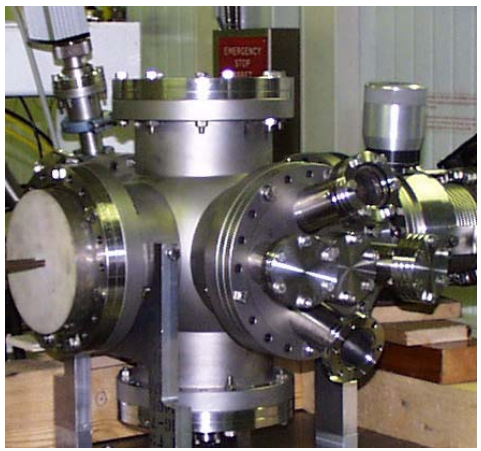


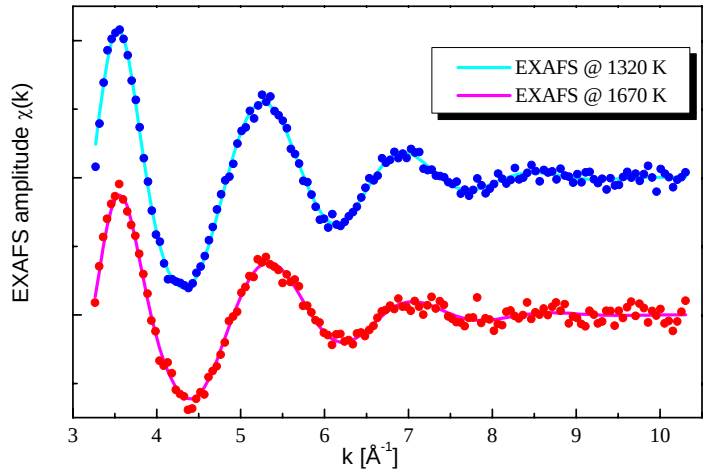
Scientific Results

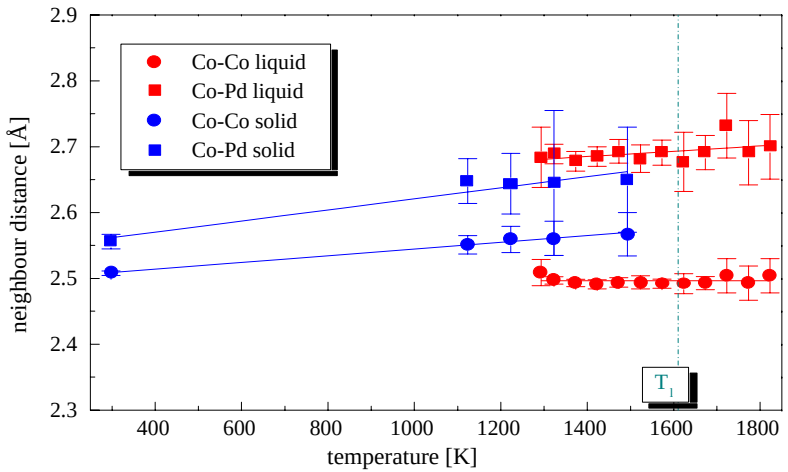
- EXAFS on CoPd ESRF, BM29
- EDXRD on Si ESRF, ID 09
- XRD on Al-Ni ESRF, ID 15
- ND on Ni, Fe ILL, D20
- QEND on Ni FRM-II TOF-TOF

EXAFS on CoPd

- 1st EXAFS on levitated sample
- Proof of principle
- Deep undercooling obtained
- Neighbour distances independent of temperature
- Coordination number decreases with temperature

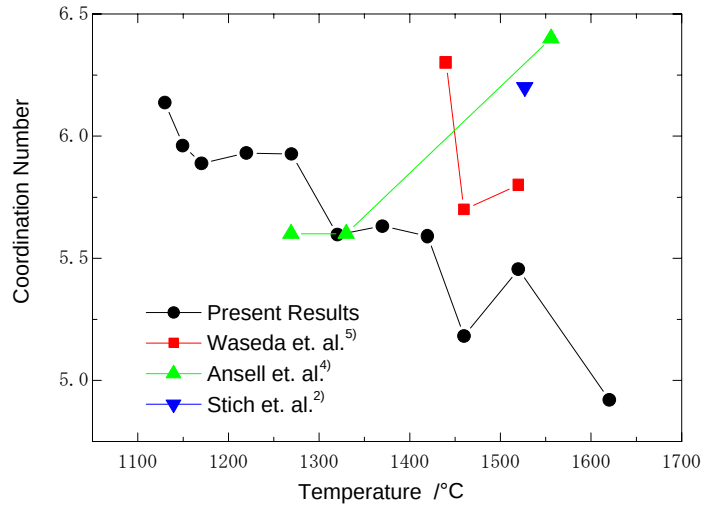


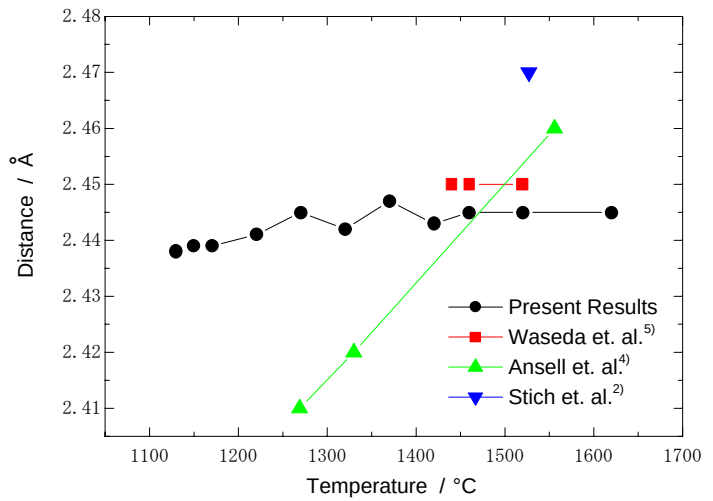




EDXRD on Si

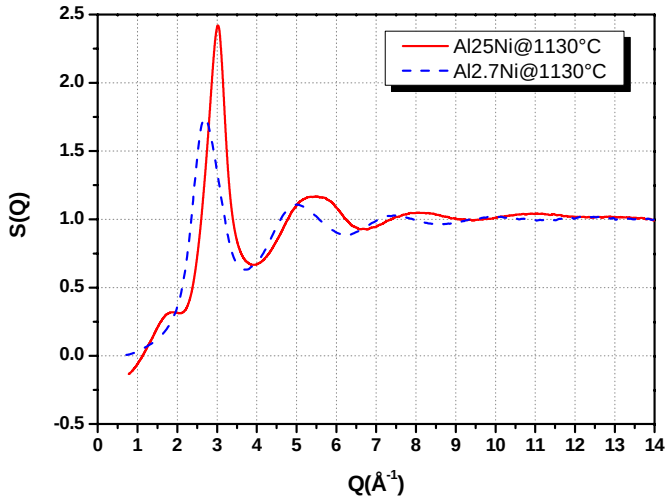
- Energy dispersive method at different angles
- Monte Carlo background correction
- Results controversial

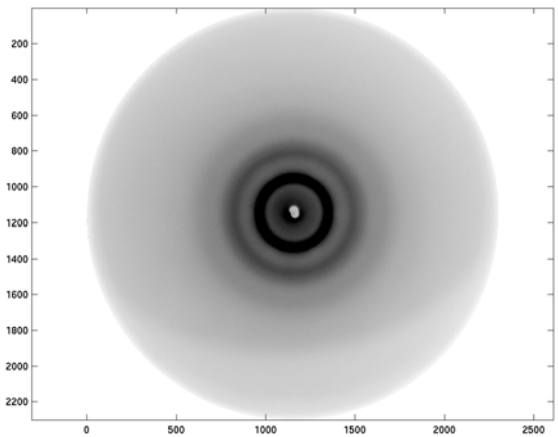


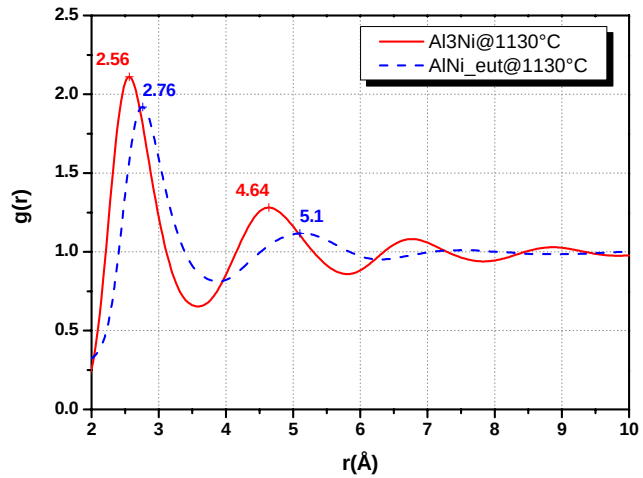


XRD on Al-Ni, Al-Fe, and Al-Cu

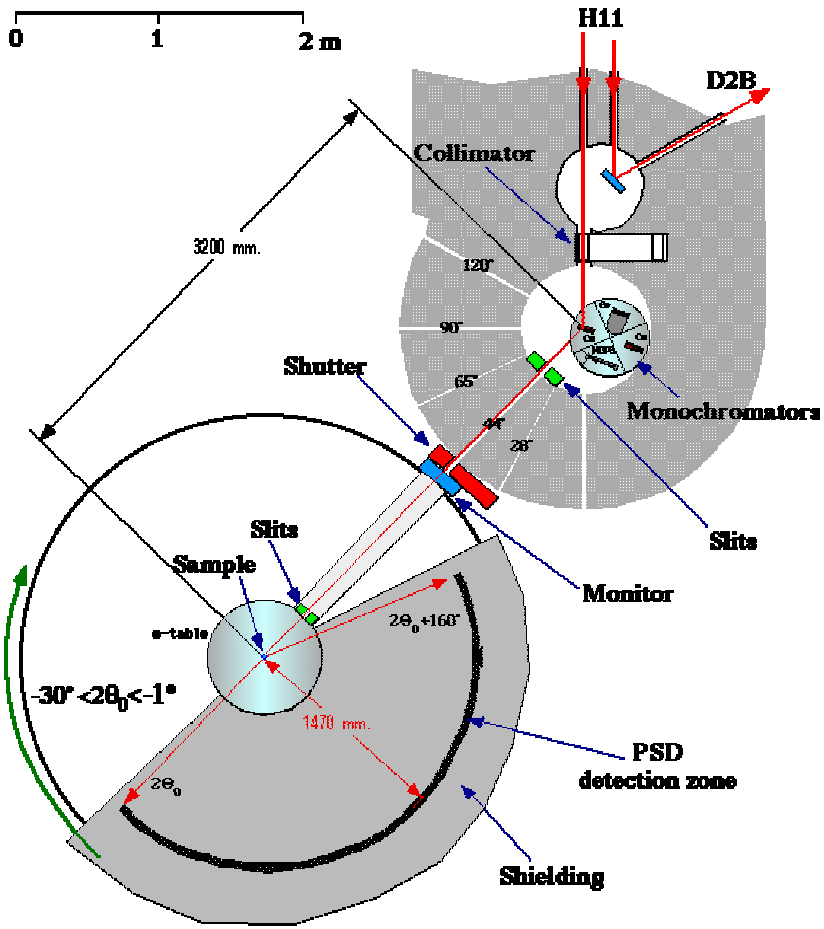
- Hybrid aerodynamic-electromagnetic levitator used
- Image plate for quick acquisition
- Cooperation with D. Price, Orleans
- Prepeak at intermetallic composition found

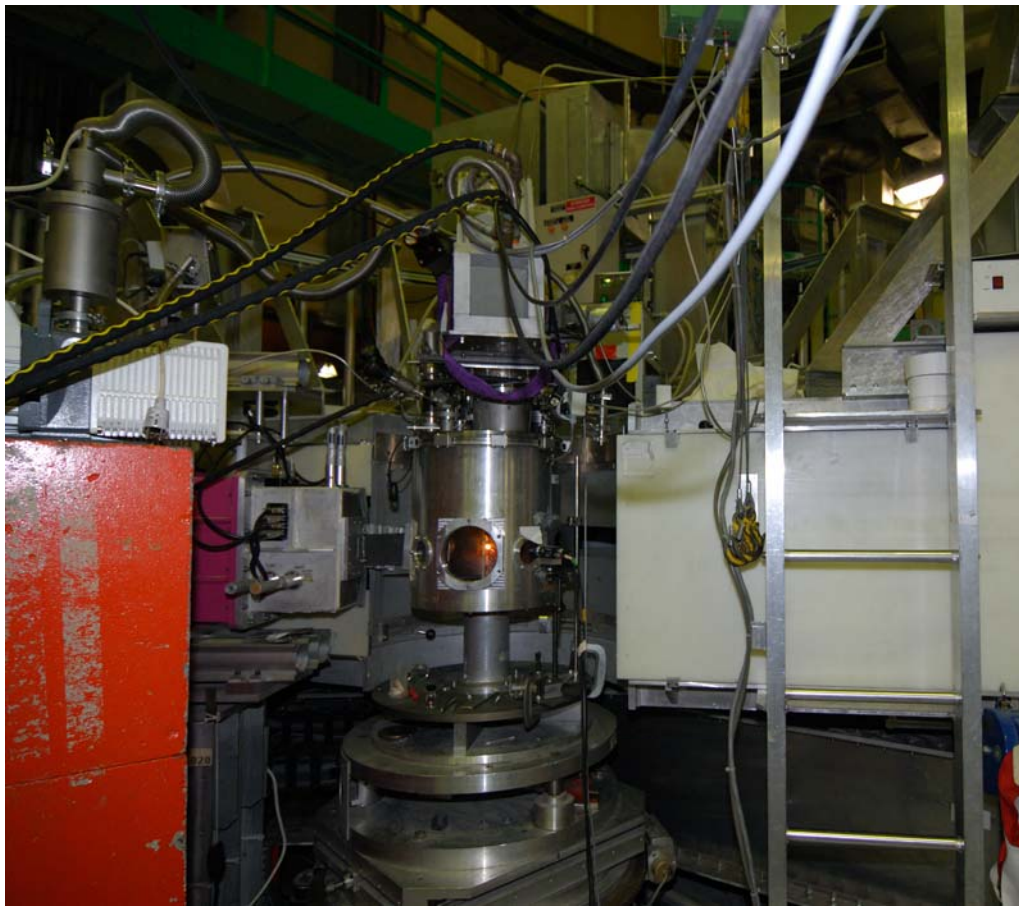




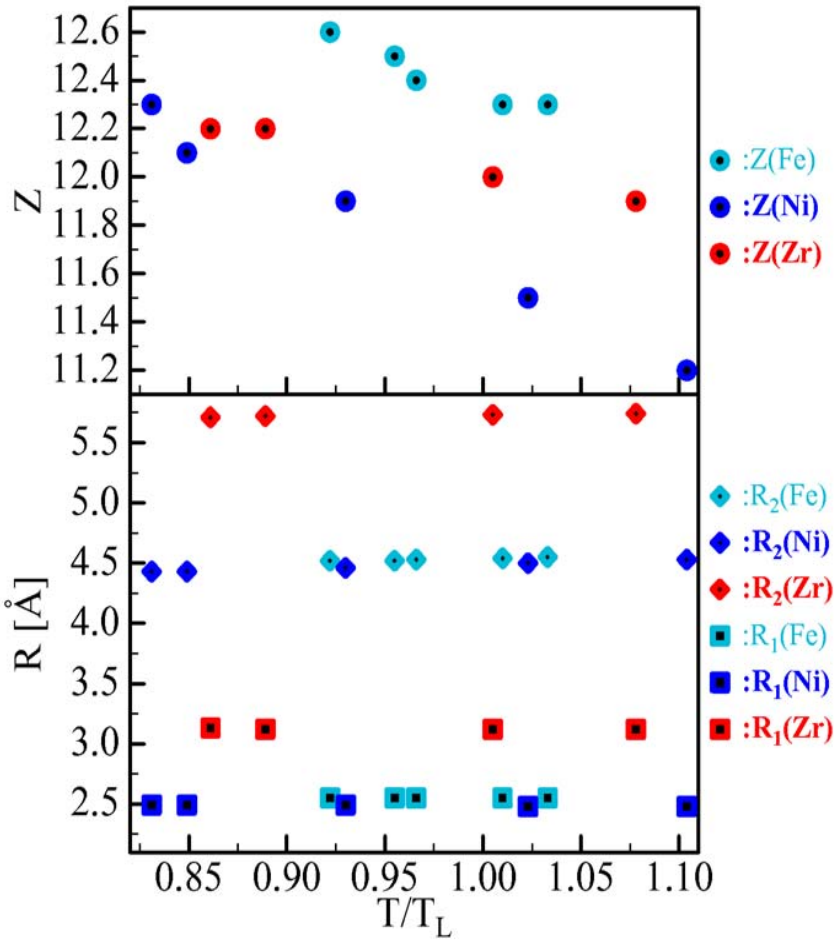


Neutron Scattering of Monatomic Metallic Melts



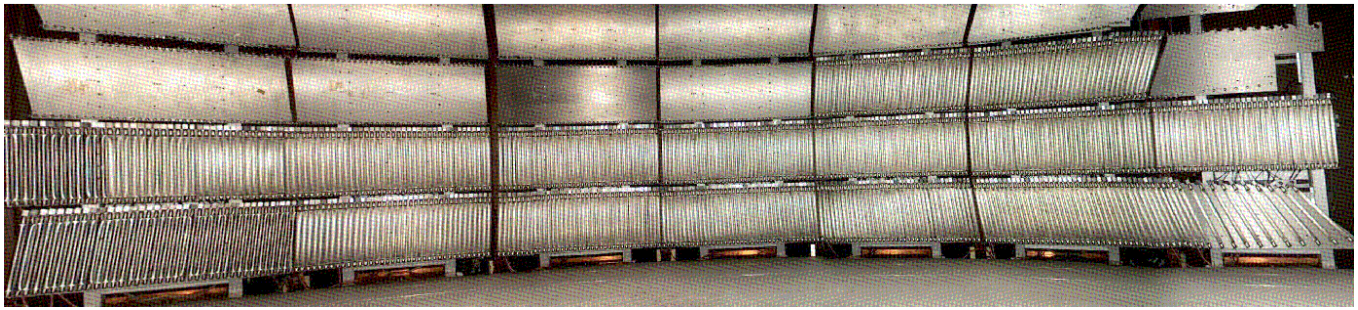


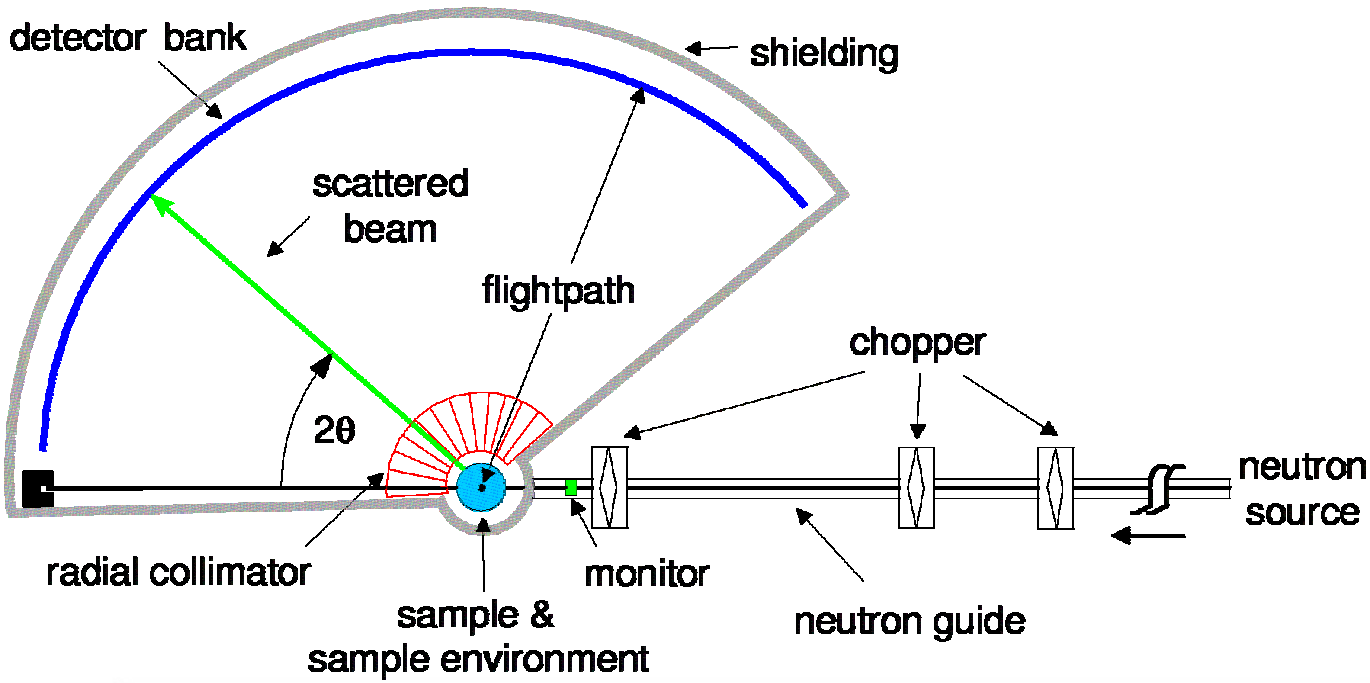
Structure Factors of Monatomic Metallic Melts



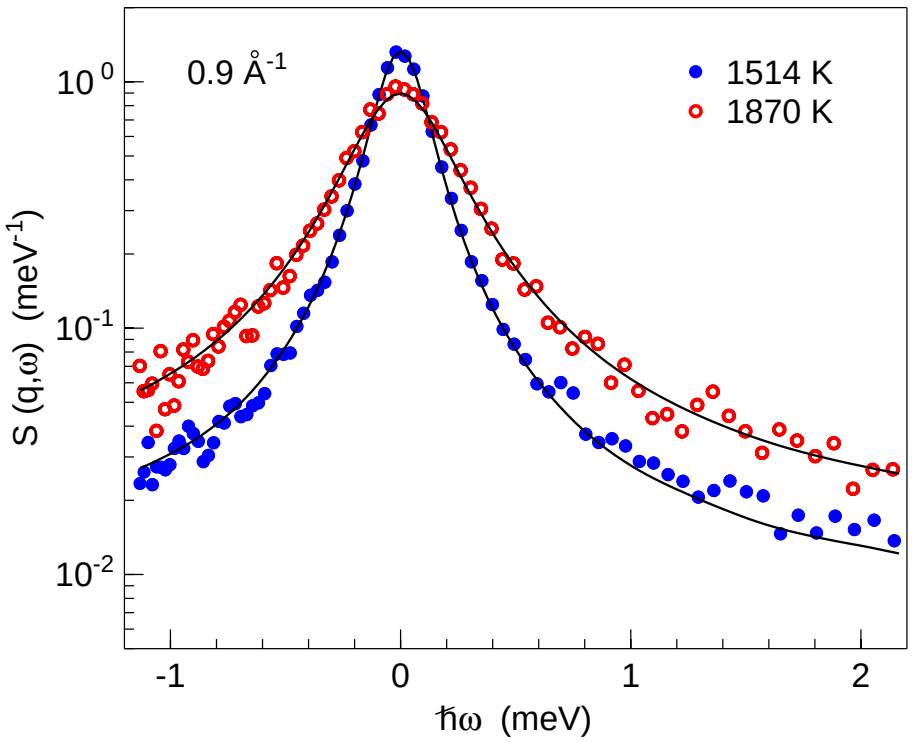
- shoulder on second oscillation of S(Q)
- first indication of icosahedral short-range order
- characteristic features more pronounced at lower temperatures
- small temperature dependence of R_1 and R_2
- $Z \approx 12$
- Z increases with decreasing T
- thermal expansion mainly governed by temperature dependence of Z

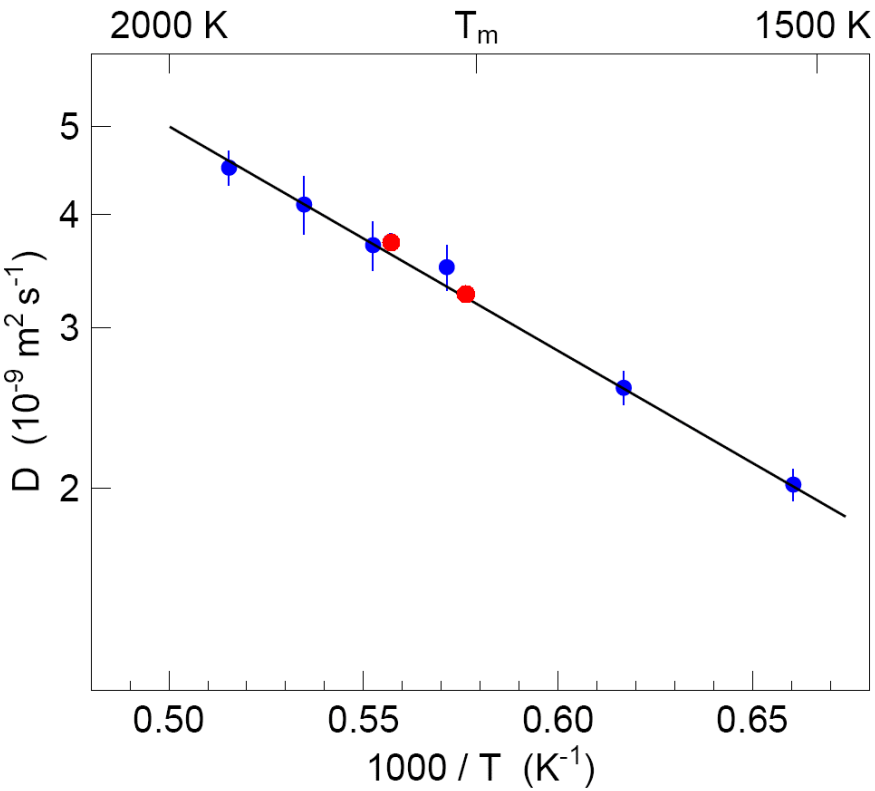
Quasielastic Neutron Scattering





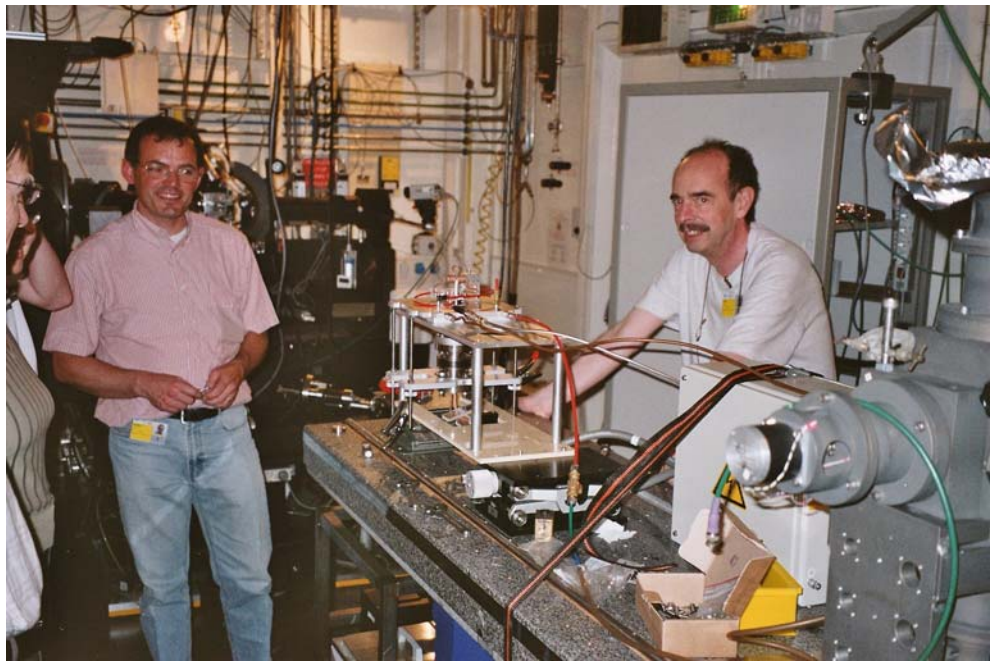
Dynamic structure factor of liquid Ni





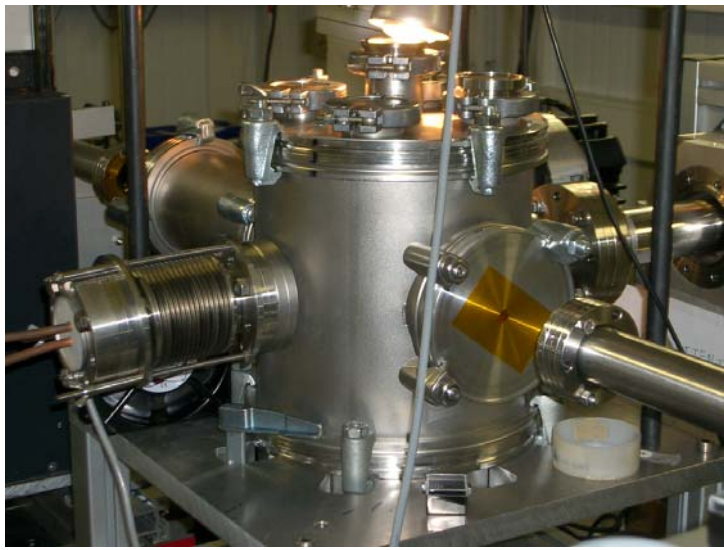
Technical Aspects

- Process Chamber
- Power Supply
- Diagnostics
- Auxilliaries
- Operational Aspects



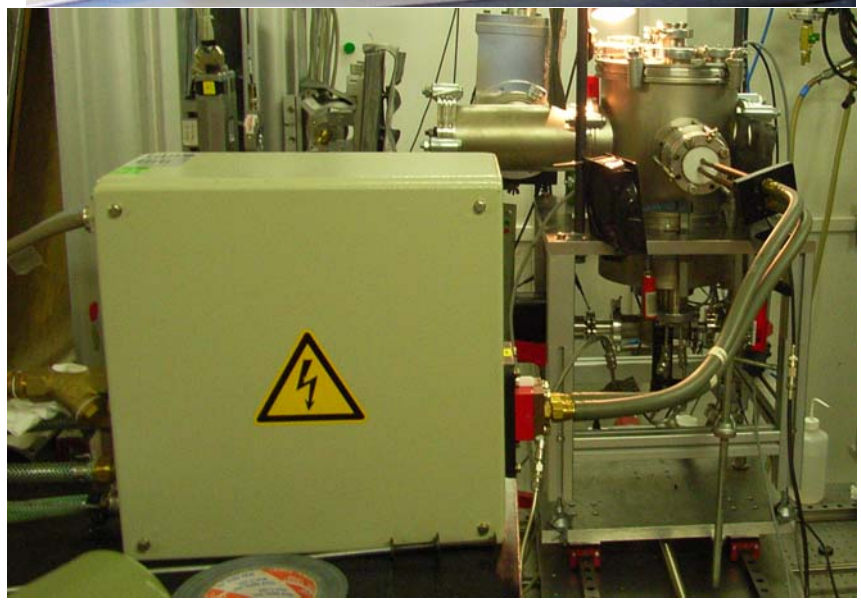
Process Chamber

- **Volume: 20 l (30 x 30 x 30 cm^3)**
- **Mass: 40 kg**
- **Material: Stainless steel**
- **Viewports (Aluminium, Kapton, Beryllium, Glass):**
  - Pyrometer
  - Video camera
  - Incoming beam
  - Scattered beam
- **Feedthroughs:**
  - Electrical for coil
  - Gas inlet, outlet
  - Overpressure valve
  - Sample manipulator
  - Flanges for pumps & vacuum sensors



Power Supply

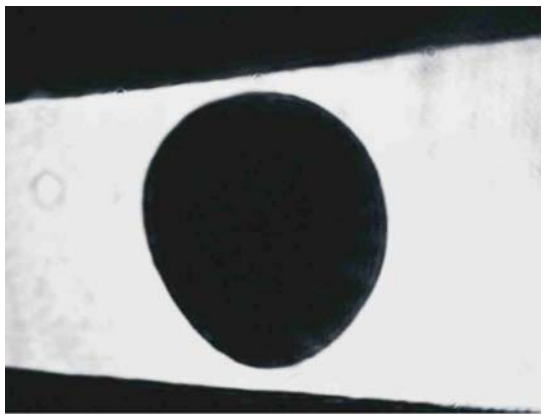
- Rf generator:
  3-phase ac, 5 kW solid state,
  air cooling, (remote)
- Oscillatory circuit:
  300 kHz, water cooled
- Coil:
  copper tube, water cooled
  one doesn‘t fit all !!



Diagnostics

- Pyrometer (for temperature measurement)
  single colour, two-colour

- Video Camera (for sample monitoring)
  CCD or CMOS
  auto-iris or auto-exposure



Auxilliaries & Interfaces

- Data logger (PC) for pyrometer signal
- Monitor for video camera
- Cooling water
- Gas supply
- Vacuum pumps

Operational sequence

- Sample loading
- Evacuation ($p = 10^{-6}$ mbar)
- Backfilling with inert gas (p = 1 bar)
- Levitation
- Beam on
- Data acquisition
- Thermal cycling
- Beam off
- Sample exchange