PECNO

Perfect Crystal Neutron Optics
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(60 months)

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Objectives:	participants :
a) Perfect crystal small-angle scattering cameras	(1, 2, 3, 4, 5, 9, 11)
b) Gradient and multiple crystals	(6, 9, 11, 14)
c) Neutron interferometry	(1, 2, 5, 7, 8, 9, 11, 12)
d) Perfect crystal storage (resonator) system	(1, 9, 10)
e) Vibrating crystals	(.. 6, 9, 11)
f) Bragg focusing and wave propagation in crystals	(2, 4, 6, 9, 11)
g) Quantum physics consequences	(1, 5, 8, 12)
h) Crystal characterization, fabrication and testing	(2, 9, 11, 13, 14)
i) Phase space manipulation	(1, 3, 5, 12)
j) Standing neutron waves	(1, 6, 13)
k) Ultra cold neutrons	(1, 2)

Rules of the Participating Teams:

- Cooperation between University institutes (1, 5, 7, 8 12 and 14) and Large Facilities (2, 3, 4, 6, 10, 11 and 13), cooperation between theory (5 and 12) and experiment (all others) oriented institutes.
  Benefits: Access to high flux neutron sources, recruiting of Young Researchers.

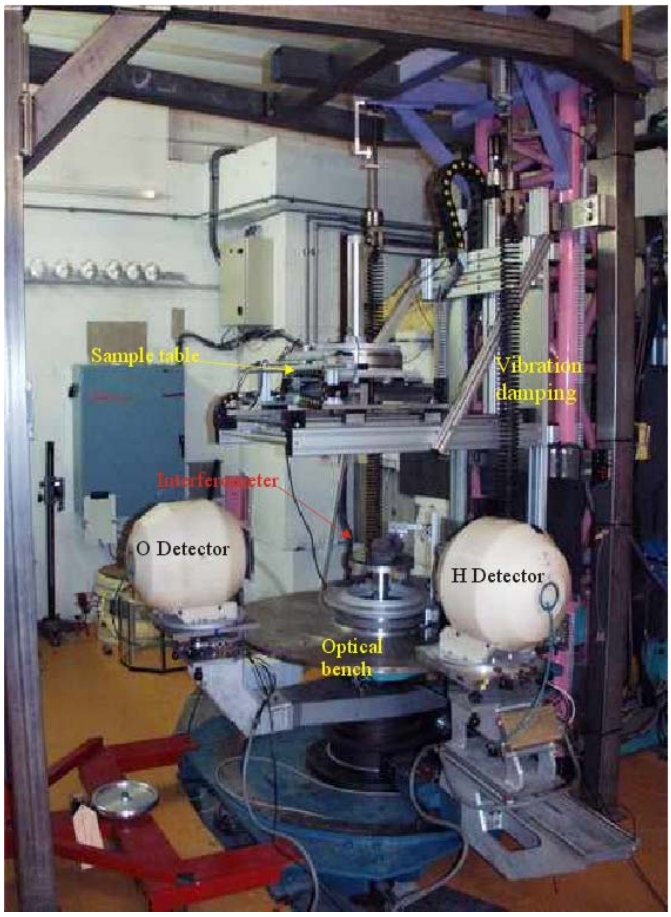
- Cooperation with industry (partner 9).
  Benefits: continuous information exchange resulting in an improved perfect crystal quality and better neutron optical components.

- Cooperation with laboratories outside the EU (4, 11, 12 and 13).
  Benefits: Access to EU programmes, highly motivated partners.

Results and Achievements:

The following scientific highlights can be defined:

- New **quantum optical phenomena** for neutron matter waves have been exploited using the upgraded **neutron interferometer** set-up installed at the high flux reactor of the Institut Laue-Langevin in Grenoble. The folowwing experimental achievements have found the highest response in the community:



- First quantum state reconstruction experiments for matter waves by means of a double loop perfect crystal interferometer.
- First observation of a confinement induced neutron phase even in cases when the neutrons do not touch the confinement walls.
- First observation of off-diagonal geometrical phases which appear in quantum physics due to topology phenomena.
- First neutron phase tomography experiments have been performed.
- With a separate long wavelength neutron interferometer gravitational phenomena have been measured with high precision.

- **Ultra small angle neutron scattering (USANS)** based on perfect crystal cameras has been pushed to a new standard where a peak to background ration above 10^5 permit new applications. Such cameras have been installed at the ILL-Grenoble, PSI-Villigen, FZ-Jülich. HMI-Berlin, NPI-Rez and ATI-Wien and they have been used for many new investigation of micro-and nano-structured materials. New tuning options have been developed to adapt the instrument resolution to the experimental requirements.

- A new **perfect crystal resonator system (VESTA 2)** has been installed at the

ISIS pulsed neutron spallation source. With that system neutron can be stored for several seconds by successive back and forth reflection between perfect crystal plates. This opens new possibilities for "interaction free" (Zeno effect like) experiments and for an advanced beam tailoring at pulsed neutron sources. The coherent energy exchange between neutrons and resonance flipper coils play an important rule for the functioning of this instrument.

- The achievements of the theory group were very impressive. New **quantum state reconstruction methods** have been developed, the question of unavoidable quantum losses has been tackled and new **Zeno-phenomena** related experiments have been proposed. Neutron quantum states have been described by Wigner- and Weyl-functions.

- The first observation of the **diffraction of macromolecules** (C_{60}) from artificially structured lattices and the observation of a **giant neutron absorption cross section** (100 M barn) of Gd-157 for ultra cold neutrons has been widely debated in the literature. These achievements were not part of the original planning but enriched the total outcome of the Network considerably.

Training:

26 Young Researchers from 10 different member states of the European Union have been hired under the contract. Among them are 15 post docs who spent 206 ½ person-months abroad and 11 pre docs who spent 106 person–months abroad.

Industry involvement:

There was a continuous contact with industry due to the industrial partner Wacker-Siltronics who is the most competent producer of perfect silicon in Europe and probably in the World.

Joint publications:

Total number of publications	89
Joint publications	61
Publications with young researchers paid by the network as authors or co-authors	29

Publications in journals with highest impact factors in the field of physics:

Nature	2
Physical Review Letters	4
Physical Review	11
Physics Letters	7

Keywords:

neutron physics, neutron optics, quantum optics

Network Home Page:

http://www.ati.ac.at/~neutrweb/pecno/pecno.html