



SCIENTIFIC HIGHLIGHTS NUCLEAR AND PARTICLE PHYSICS

Ultra-cold neutron facility PF2

MONOPOL, a travelling-wave magnetic neutron spin resonator for tailoring polarised neutron beams

Since the early 1960s it is known that spin resonance in undulatory static magnetic fields allows for wavelength-selective spin flip of polarised neutrons. Implementing a novel travelling-wave technique, we have developed this concept towards a resonator which does not only allow to monochromatise the neutron beam but also to chop it into a sequence of pulses short enough for time-of-flight applications. The outstanding performance of such a resonator which was optimised for very cold neutrons could be demonstrated successfully at the PF2-VCN beam line.

AUTHORS & REFERENCES

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[1]] G.M. Drabkin, Sov. Phys. JETP 16 (1963) 282
 [2]] Ch. Gösselsberger *et al.*, Physics Procedia 42 (2013) 106

Up-stream view of the experimental set-up: the resonator with 48 individual elements is shown together with the individual supply lines from the current sources on its top. A broad-band current sheet spin flipper for polarisation inversion of the neutron beam can be seen in the foreground. The complete experiment has been placed in a He atmosphere to reduce neutron scattering and suppress VCN absorption. As shown already in the 1960s [1], the combination of a static vertical and a spatially alternating horizontal magnetic field constitutes an NMR-like system for polarised neutron beams, with the peculiarity that for given spatial period and strength of the vertical field each neutron creates its own '*resonance*' frequency according to its individual speed. Clearly, when placed between two polarising neutron mirrors such a resonator acts as neutron monochromator. The conventional design of such a resonator employs a thin meander-shaped metal conductor foil where each turn of the foil defines a single resonator element. Increasing the number of such elements improves the achievable wavelength resolution but evidently increases also the length of the resonator. Neutron pulses may be generated by switching the foil supply current on and off with the consequence that the achievable minimum pulse length is defined by the overall resonator length.

However, in our novel '*travelling wave*' technique the undulatory resonator field is applied in synchronisation with the resonant neutron pulse during its passage through each of the consecutive



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resonator elements. As a consequence, the minimum pulse length is defined only by the length of a single resonator element and hence be up to two orders of magnitude shorter than in the conventional mode. The experimental realisation of this novel technique, which allows for a complete decoupling of wavelength and time resolution, is a major step towards the development of electronically tuneable neutron monochromators and choppers of utmost flexibility. As additional feature, the concept can be applied across the complete thermal and cold neutron spectrum.

We have built a resonator composed of 48 elements (figure 1), each consisting of a 11.6mm thick prismatic single-turn coil made of a 0.1 mm aluminium sheet and fed by an individually controllable current source which can be switched on and off within about 1 microsecond. This resonator was tested at the PF2-VCN beamline with a polychromatic beam of very cold neutrons, polarised and analysed by a pair of Fe/SiGe-based supermirrors. We established 'Dark-field' conditions by inverting the neutron polarisation over the complete incoming neutron spectrum by means of a broad-band current sheet spin flipper. Spectral analysis was performed by employing a single-disk chopper with about 5 ms opening time when operated at 10Hz repetition rate (chopper-detector distance: 2.7 m). The blue symbols in figure 2 represent the incoming VCN spectrum obtained with the resonator and the current sheet flipper switched off. Activating both



Time-of-flight spectra of the VCN beam as measured by means of a mechanical single-disk chopper: blue symbols show the total spectrum when the resonator is turned off, red symbols the combined effect of the neutron resonator and the broad-band spin-flipper; black symbols indicate the neutron background due to non-ideal neutron polarisers when the resonator is turned off.

results in the spectrum represented by the red symbols. The effect of spatial neutron spin resonance is clearly seen from the reduced spectral width of the detected neutron distribution (which is of course the result of a convolution of the actual spectrum with the transmission function of the disk chopper). Indeed, its width is dominated by the chopper opening time, while the wavelength resolution of the resonator is fully compatible with the theoretical value of 3% for a resonator consisting of 48 elements.

With this resonator we have realised at PF2-VCN the first travelling wave spin resonance at a white neutron beam ever (**figure 3**). Due to the fast switching time of our current sources the magnetic field is switched on practically instantaneously for the slow neutrons. Each resonator element has been activated for a certain time interval only (1.5 and 10ms, respectively). Now, the resonator itself acts as a neutron beam chopper which is able to create neutron pulses of arbitrary length. As a clear advantage, the travelling wave mode produces much sharper neutron pulses than the conventional mode. Eventually this might be of value for novel ESS instrumentation.

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Tailoring the temporal structure of the neutron beam by pulsed operation of the resonator. The typical time scale for VCN is milliseconds. In the novel travelling wave (TW) mode the edges of the pulses are considerably sharper than in conventional mode (CM) where the resonator is switched on and off as a whole.