INTERCHANGING SOURCE AND DETECTOR: RECIPROCITY AND ITS VIOLATION IN SCATTERING EXPERIMENTS

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Keywords: reciprocity, photon scattering, neutron scattering, Mössbauer, synchrotron
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The reciprocity principle [1], which states that the interchange of source and detector does not change the scattering amplitude in a scattering experiment, cannot be derived from first principles and, consequently, is not necessarily fulfilled. Reciprocity is often confused with time-reversal invariance or with rotational symmetry the latter being sometimes believed to result in the symmetric shape of the diffuse scatter in X-ray or neutron reflectometry experiments. The question when reciprocity is fulfilled or violated is, therefore, of practical importance in X-ray and neutron scattering, Mössbauer spectroscopy, etc.

A general reciprocity theorem has recently been formulated by Deák and Fülöp [2]. They emphasize that, especially for wave phenomena with more than one spin/polarization degree of freedom like scattering of photons and of neutrons, reciprocity is more general than time reversal invariance, and can occur for absorptive scattering media as well. Due to its high absorption cross section and polarisation sensitivity, nuclear resonance scattering of synchrotron radiation is ideally suited for studying reciprocity and its violation. A recent experiment [3] has shown that, in a nuclear resonance scattering experiment, it is easily possible to switch between reciprocal and a nonreciprocal arrangements of two magnetized α–^{57}Fe foils, which had neither time reversal invariance nor 180°–rotational symmetry. The violation of reciprocity in the non-reciprocal arrangement turned out to be about 10^3, i.e., by orders of magnitude higher than ever observed previously.

References

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