Saturation effects on coherent backscattering with cold trapped atoms

Short Visit Grant - Final Report
Date of visit (starting date): 08/11/2004
Duration: 14 days

Purpose of the visit

The purpose of the visit was to introduce a new member of the Dresden team, Dr. Carlos Viviescas, into our long-standing collaboration with Robin Kaiser's and Christian Miniatura's group at Institut Non Lineaire de Nice (INLN). In particular, C. Viviescas was expected

- to familiarize himself with the experiments in Nice, and to exchange and compare the recent theoretical results of both groups [1, 2];
- to identify suitable experimental observables in the Nice experiment, which will allow to observe the abovementioned dynamical signatures;
- to initiate a common study on possible consequences of saturation for the onset of strong (i.e., Anderson like) localization at increased atomic densities.

Work carried out during the visit

In the course of Dr. Viviescas' visit to the Cold Atoms Group at INLN, the following activities were carried out:

- A guided visit to the CBS experiments with cold atomic gases (rubidium and strontium): These two experiments constitute the core of the Nice-Dresden collaboration.

  Details concerning the density of the atomic clouds, and how to increase it in order to enter the regime of strong localization for light were discussed. The relevance of atomic saturation, i.e. of the nonlinear response of the system to large field intensities, for radiation transport across the atomic sample was also commented – in particular its role as a quantifier of incoherent processes. In addition, in the context of models of random lasers involving clouds of cold atoms, possible amplification mechanisms were discussed.

- C. Viviescas delivered a talk on the "Emission spectrum of random lasers", presenting his recent work on the spectral properties of laser light emission from open chaotic cavities with overlapping resonances [3]. Emphasis was put on the fact that laser light emission from disordered amplifying media is possible even far from the regime of strong localization of light [4].

- Simultaneously to C. Viviescas' visit, Dr. D. Delande, Dr. B. Grémaud, and Dr. T. Wellens from Laboratoire Kastler Brossel in Paris spent a couple of days at INLN. Several informal discussions helped to strengthen the ongoing collaboration between the three groups. The following subjects were touched upon:

- Modelling random lasers with quantum graphs: Quantum graphs – as the arguably simplest manifolds for which chaotic dynamics can be identified – may allow for an extensive, yet computationally economic, study of random lasers [5].
- Effects of inelastic two photon scattering processes in the Coherent Back Scattering (CBS) of light from a cloud of two level atoms: A perturbative treatment closely related to recent work of the Nice and Paris groups was discussed [6].
- Feasibility of random lasing from a dilute gas of cold two-level atoms: In particular, we addressed the impact of the saturation of the scattering medium for the multiple scattering feedback.

Future collaboration with host institution

- Only recently the Dresden group [2] has proposed an approach to CBS that is none-perturbative in the atom-field coupling strength and, therefore, well-suited for studies of CBS even at large field intensities. On the basis of this master equation formalism, we shall study the imprints of CBS on both the spectrum of the scattered radiation, as well as on its photocount statistics, in close contact with experiments currently under preparation at INLN.
- In a common theoretical effort, following the discussions during C. Viviescas' visit, we will address the role of atomic saturation for the onset of strong (i.e., Anderson like) localization at increased atomic densities. In a first step, we will derive estimates for the critical injected light intensity which induces inelastic scattering events. Assuming localized light modes with localization lengths of a few optical wavelengths, only a few photons might suffice to saturate the atoms located in that region, thus counteracting the interference phenomena responsible for strong localization.
- Independently of the possible emergence of strongly localized light modes in the atomic scattering sample, random lasing may occur in disordered amplifying media even far from the strong localization regime. Indeed, recent theoretical and experimental work [4] demonstrates the emission of laser light in the weak disorder limit, with $k\ell \approx 35$ to 5800 (with k the wave vector of the incident radiation, and ℓ the mean-free path for the scattered photons). This is comparable to typical values in the INLN experiments, where the typical atomic peak density in the cloud is of the order of 10^{10} atoms/cm^3, leading to $k\ell \approx 1000$. Given C. Viviescas' expertise on random lasers in the weak disorder limit, this research direction defines a perfect merger of both group's interests and competences, and will be followed jointly.

References

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[5] C. Viviescas and J. Madroñero, in preparation.

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