High resolution laser spectroscopy of cold atoms and molecules

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Abstract

ONE OF the fields of experimental physics that has been revolutionised by the development of the laser in the past 50 years is the field of spectroscopy. Generally spectroscopy can be described as the study of the interaction of light and matter, and includes a multitude of specialised techniques facilitated by lasers. This presentation will focus on the role and advantages of lasers in the basic technique of measuring the unique spectrum of narrow spectral lines corresponding to wavelengths absorbed by a specific atomic or molecular species in gas phase. Spectroscopic measurements can be applied to identify and quantify the atomic or molecular species in a sample and to determine the temperature of the sample and speed of the atoms or molecules. This technique is of particular importance if the sample under study is not accessible in any other way, such as those in astrophysics and space science, including stars and the interstellar space.

A laser producing light in a narrow spectral range (i.e. light of one colour) of which the wavelength can be tuned is an ideal light source for spectroscopy, as it makes it possible to optimise both the spectral resolution and the signal strength, in contrast to conventional spectrometers where optimisation of one compromises the other. Pulsed lasers additionally offer the possibility to observe the time evolution of the sample after the laser pulse has interacted with the sample. In this presentation several important effects in the interaction between laser light and atoms or molecules will be introduced and subsequently the exploitation of these effects in two different high resolution laser spectroscopy experiments will be discussed.

In the first experiment a novel tuneable vacuum ultraviolet laser source is combined with a gas sample cooled in a supersonic gas jet. Every available mechanism is used to optimise the experiment to detect the weak absorption signals of rare carbon monoxide (CO) isotopomers and forbidden transitions of 12C16O. The results find direct application in astrophysics. In the second project the interaction of the light of tuneable external cavity diode lasers with rubidium atoms is investigated. It is discussed how a cold spectrum is obtained using a sample at room temperature, and how light is employed to cool and trap atoms in vacuum.