

Emerging beam resonances in atom diffraction from a reflection grating

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Abstract

It is a general phenomenon in wave optics that diffraction by a periodic surface shows peculiar intensity variations in the outgoing beams when conditions are such that a diffracted beam just emerges parallel to the surface. This was first observed by Wood in 1902 and is known as Wood anomalies in light optics [1]. Rayleigh in 1907 first traced back Wood anomalies to grazing emergence of a diffracted beam [2]. Later on Wood anomalies were categorized into two cases, one (sharp anomalies) related exclusively to the emergence of a diffracted beam (Rayleigh-Wood anomaly) and the other (broad anomalies) to resonance effects [3, 4].

In atom optics a behavior in analogy to the resonance type anomaly has been investigated for a long time under the name of selective adsorption [5], which was first observed by Estermann and Stern in 1930 in the scattering of helium atoms from crystal surfaces [6]. It is accounted for by a bound state of the atom-surface interaction potential. On the other hand, Rayleigh-Wood anomalies which, in atom diffraction, are referred to as *emerging beam resonances* have not been observed in atom surface scattering experiments, although they have been predicted by theory [8, 9].

Here we report the first observation of emerging beam resonances in atom optics. Helium atom beams are diffracted from a plane ruled grating at near grazing incidence. By varying the incidence angle we observe the resonances at the Rayleigh incidence angles in two ways; (i) the total reflectivity of the grating increases steeply, (ii) the intensity curves of the diffracted beams and the specular beam exhibit abrupt changes of their slopes. We

adopt the multiple scattering approach of Rayleigh [2] and Fano [3] to explain basic features of our observations. Our results complete the analogy between photon optics (*Rayleigh-Wood anomaly* and *resonance type Wood anomaly*) on the one hand and atom optics (*emerging beam resonance* and *selective adsorption*) on the other hand.

Keywords: atom optics, Wood anomalies, emerging beam resonance, grating diffraction

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