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INTERACTION-FREE MEASUREMENT WITH MATTER WAVES

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In the early 1990's, A. Elitzur and L. Vaidman proposed an interaction-free measurement (IFM) that allows researchers to find infinitely fragile objects without destroying them. But the Elitzur-Vaidman IFM has been used only to determine the position of opaque objects. We propose a non-trivial extension of such a technique with matter waves, which allows measurement of classical fields. And we show severe limitations when we talk about gravitational fields.

Key words: foundations of quantum mechanics, interaction free measurement, matter waves.

1. INTRODUCTION

Avshalom Elitzur and Lev Vaidman proposed a technique for an interaction-free measurement (IFM) that allows researchers to find infinitely fragile objects without destroying them [2]. Some experimental demonstrations of this prediction have been obtained [5, 6]. For a recent review on the theoretical and experimental aspects of the IFM proposed by Elitzur and Vaidman, see [10].

Nevertheless, Elitzur-Vaidman IFM has been used only to determine the position of non-transparent objects. The original scheme is based on a Mach-Zehnder interferometer (see Fig. 1). Single photons are emitted to the first beam splitter (BS_1) with a transmission coeffi-

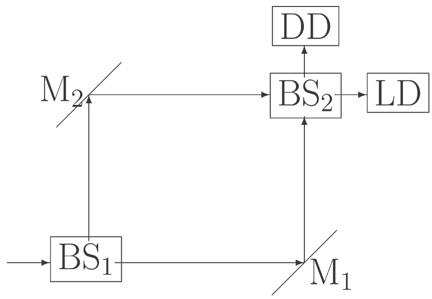

Fig. 1. Mach-Zehnder interferometer.

cient 1/2. Next, the transmitted and reflected parts of the photon wave are reflected by mirrors M_1 and M_2, respectively. These reflected waves are reunited at the beam splitter BS_2, whose transmission coefficient is 1/2. Two photon detectors, LD (light detector) and DD (dark detector), are positioned according to Fig. 1. The geometric arrangement is made in such a way that all photons are detected at LD and no photon is detected at DD, due to the self-interference of photons.

If any opaque object – like, for example, an infinitely fragile object that explodes when it is hit by any photon – is put on the way, say, between BS_1 and M_2, then there is no interference phenomenon. In this case, there is a 25% chance that DD detects a single photon sent through the interferometer. If a single photon is detected at DD after it was sent to the interferometer, then we can know for sure that there is something inside the interferometer. This is called an interaction free measurement in the sense that there is a 25% probability of knowing that there is in fact a photon-sensitive bomb inside the interferometer without exploding it. The fact that that bomb is found in a region of space without exploding it is evidence that there was no interaction between the photon detected at DD and the bomb. Obviously, if a photon is detected at LD, we know nothing at all about any object inside the interferometer. Besides, there is still a 50% chance of any single photon emitted to BS_1 be reflected and hit the bomb. In this case, we find the bomb with an interaction measurement, since it actually explodes.

In this paper, we propose an extension of such a technique allowing researchers to measure electric and magnetic fields generated by macroscopic sources. In principle, even gravitational fields are measurable by an analogous experiment. One of the main differences between Elitzur-Vaidman's proposal and ours is the use of matter waves instead of photon waves. With matter waves we can get information that is not available by means of photon waves. Such a proposal is a new motivation for the improvement of matter waves interferometry with