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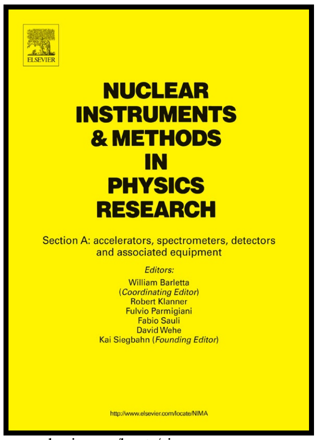

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PII: S0168-9002(17)30516-8
DOI: http://dx.doi.org/10.1016/j.nima.2017.04.041
Reference: NIMA59829

To appear in: *Nuclear Inst. and Methods in Physics Research, A*

Received date: 27 February 2017
Accepted date: 27 April 2017

Cite this article as: P. Lansonneur, P. Bräunig, A. Demetrio, S.R. Müller, P. Nedelec and M.K. Oberthaler, Probing Electric and Magnetic Fields with a Moiré Deflectometer, *Nuclear Inst. and Methods in Physics Research, A* http://dx.doi.org/10.1016/j.nima.2017.04.041

Probing Electric and Magnetic Fields with a Moiré Deflectometer

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Abstract

A new contact-free approach for measuring simultaneaously electric and magnetic field is reported, which considers the use of a low energy ion source, a set of three transmission gratings and a position sensitive detector. Recently tested with antiprotons [1] at the CERN Antiproton Decelerator facility, this paper extends the proof of principle of a moiré deflectometer [2] for distinguishing electric from magnetic fields and opens the route to precision measurements when one is not limited by the ion source intensity. The apparatus presented, whose resolution is mainly limited by the shot noise is able to measure fields as low as $9\,\mathrm{mV\,m^{-1}\,Hz^{-1/2}}$ for electric component and $100\,\mathrm{\mu G\,Hz^{-1/2}}$ for the magnetic component. Scaled to 100 nm pitch for the gratings, accessible with current state-of-the-art technology [3], the moiré fieldmeter would be able to measure fields as low as 22 $\mathrm{\mu V\,m^{-1}\,Hz^{-1/2}}$ and 0.2 $\mathrm{\mu G\,Hz^{-1/2}}$.

Keywords: Fieldmeter, Lorentz force, Moiré effect

1. Introduction

Depending on the frequency range considered, electric field meters usually rely on different operating principles. Antennas reach the best performances to measure time-varying electric fields, when frequencies typically overcome 100 kHz. Reference [4] gives the example of a dipolar double probe, able to measure electric fields with a sensitivity of $E_{\min} = 1\,\mathrm{mV\,m^{-1}}$ at several MHz. Instead, the highest sensitivities for static or low-frequency electric fields are achieved with “voltmeter-type” sensors where the potential difference between two plates placed apart is precisely measured. Krupka et al. [5] reports for instance a sensitivity of $2\,\mathrm{\mu V\,m^{-1}\,Hz^{-1/2}}$ at 100 Hz with plates placed 33 cm apart. Although those devices show a high sensitivity, the field magnitude is indirectly evaluated by the amount of charges it induces.

Another category of apparatus builds on free charges in vacuum. The use of particle beams, combined with a position sensitive detector, allows to perform precise contact-free measurements over large experimental volumes and to probe directly the field itself. The steered electron field sensor [6], in which two anodes measures the shift induced by an external electric field on an electron beam, is for example able to resolve a field of $34\,\mathrm{mV\,m^{-1}\,Hz^{-1/2}}$ at 10 Hz. In its current state, such a device is however not able to determine if the shift measured is due to an electric or a magnetic field. A similar approach is here reported, which presents the advantage of distinguishing the electric from the magnetic field component with the same device.

2. Moiré Fieldmeter

2.1. Moiré principle

The principle of the moiré fieldmeter can be seen as an extension of the simple setup depicted in figure 1(a) In this configuration, a non-collimated beam passes through two apertures separated by a distance L, which constrain the trajectories of the particles reaching the detector. Undeflected particles such as neutral atoms conserve straight trajectories throughout the whole apparatus while particles submitted to a force will experience an acceleration in the vertical direction leading to a parabolic trajectory. The shift Δy between the two impacts on the position sensitive detector is given

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