ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPME076

OSCILLATING WIRE AS A "RESONANT TARGET" FOR BEAM TRANSVERSAL GRADIENT INVESTIGATION

Arutunian S.G., Margaryan A.V., Yerevan Physics Institute, Yerevan, Armenia

Abstract

Measurements of secondary particles/photons reflected/generated from an oscillating wire in synchronism with the wire oscillation frequency are proposed. The differential signal on wire maximal deviations at oscillation process can provide a fast signal proportional to beam profile gradient. Idea of using such "Resonant Target" for beam transverse gradient profiling was tested with lightening the oscillating wire by a laser.

INTRODUCTION

The typical wire scanner consists of the target wire on which scattering of the beam occurs and secondary particles/photons detection system [1]. The quantity of the detected particles/photons above some background is proportional to the number of scattered particles and provides information on measured beam profile. To be sure that only scattered particles/photons contribute to measurements, the detection system is normally placed far away from the wire area. So the whole system becomes complicated and stretched [2].

The usage of oscillating wire makes the system more compact and simple. The principle of measurement here is based on the dependence of wire natural frequency on wire tension which in fact depends on wire temperature [3, 4]. So the information of how many particles/photons penetrate the wire is obtained by precise measurement of wire oscillations frequency. The thermal balance is needed at each measurement position, which increases the response time of the sensor to many seconds [5].

Proposed new method is based on the idea of using oscillating wire as a target and maintaining the resonant methods to detect particles/photons aroused at scattering of the beam. Such device should have compactness of vibrating wire monitors and fast response comparable with sub millisecond wire oscillations period.

Experimental realization of the method is fulfilled on the profiling of laser beam. As detection instrument the fast photodiodes are used.

The frequency output of the oscillated wire also used as additional signal described laser beam profiling.

METHOD

General Notes

Actually the proposed method gives a possibility to extract the signal from beam scattering on the wire using resonant characteristics of the signal when the wire is oscillating. This extraction can be made by different ways; we used a simple idea to compare the output signal at two opposite limit positions of vibrating wire. We make sure the measurements should be done fast enough to recognize the phase pattern of oscillations process.

This difference arises if at these positions the density profile is varied. In Fig. 1 the main view of the concept is presented. The first harmonic oscillations are generated in the plane orthogonal to the beam axis (in plane of Fig. 1).

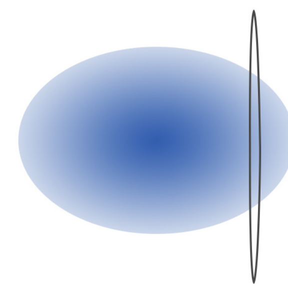

Figure 1: The beam is presented by ellipse with graded color corresponding to beam density. Wires at two extreme positions during oscillations are drawn. At the left position more particles penetrate the wire than at the right position.

Origin of wire oscillation can be different: either oscillation on the natural frequency of the wire generated by special auto generation circuit, or forced oscillation on the frequency of the external generator. What is important in any case is that the amplitude of mechanical oscillation should be stable to make the displacement of the wire in space precisely definitive.

In the case of natural oscillations the measurement of changed frequency responding to the temperature of the wire provides additional information on the beam profile recovering. Disadvantage of this method can be some difficulties of natural oscillations generation process. To reach a good condition of auto generation the quality factor of the system should be as high as possible. It makes some restrictions on magnet system that should be more situated to oscillations geometry. In case of first harmonic generation it does mean that the placement of magnet in center of wire is preferable. By some loss of quality factor, magnet can be divided at two part and split to ends of wire, but in any case the opening space for beam acceptance reach about only one half of wire length. Also it should be noted that sufficiently great response time of wire temperature is needed for balancing with the source of heat, namely the beam energy deposition into the wire.

In case of forced generation the magnets can be shifted tightly to wire ends with enlargement of beam acceptance space.

In the experiments described below we used the natural oscillations of the wire.

5th International Particle Accelerator Conference IPAC2014, Dresden, Germany JACoW Publishing
ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPME076

Photon Measurements Accessories

For wire oscillations generation we used the electronic circuit developed for vibrating wire monitor [5]. Circuit also provides the precise measurements of frequency and data acquisition and transfer to computer via RS232 serial port.

The photon measurement unit was based on the usage of fast wide wavelength photodiodes: VBPW34S with spectral range 430-1100 nm and rise/fall time 100 ns (at load 1 kOhm). In our case the load was 120 kOhm so the time characteristics were better than 100 ns. Also a photodiode VTB8440 was tested with inferior characteristics.

Front-end Electronics

The signal from photodiode was amplified by amplifier INA127 and then transferred to sufficient fast analogue to digital converter MCP3301 with 100 ksps sampling rate and minimum clock speed during the conversion cycle 85 kHz. For analogue signals measurements microcontroller PIC18F252 was used with 4 MHz quartz generator and 16 MHz FOSC. Communication with computer serial port RS232 was made via RS232/RS422 converter which allows to use few microcontrollers in line simultaneously.

Software

At first stage the data transfer between front-end electronics to the computer was done as 1000 measurements package with 1 Hz rate. Sine-shaped signal of generation current output after amplification passed through the comparator to obtain meander signal for measurements by microcontroller. To adjust the start of measurement at two maximal deviations of the wire from unexcited position the programmable delays were introduced. Values of delays were coordinated experimentally (see Fig. 2).

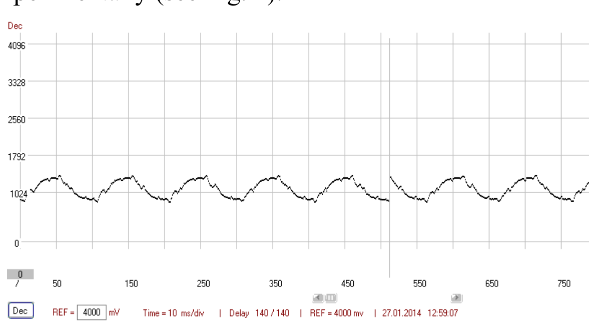

Figure 2: Signal from photodiode in case of no oscillating wire. Experiment was done at 50 Hz indoor lighting. Averaging on 1000 measurement points makes measurement smooth in cumulative chart (see Figs. 5, 6).

Oscillation Wire

As oscillating wire we used a stainless steel wire with 100 μm diameter and 80 mm of length. To provide the first harmonic generation two closed magnet poles are used so the acceptance for beam was about 30 mm. Wire oscillations occur at frequency about 1000 Hz. Auto generation circuit current reaches a few mA.

To measure the mechanical oscillations amplitude the wire was lightened by LED with frequency equal to wire oscillations frequency. At aroused stroboscopic pattern the amplitude of mechanical oscillations was detected as 200 μm from peak to peak positions. The phase synchronizations of mechanical oscillations with generating current were not investigated. Adjustment of measurement times was done by introducing of delays after generating signal cross the null.

EXPERIMENT

For the first experiment a simple layout was prepared on base of the semiconductor laser and ready-to-use vibrating wire sensor.

The experiment setup is presented in Fig. 3. The vibrating wire sensor was mounted on the movable platform with μm feed. At this stage of investigations the fast movement was not at the focus of our interest so the movement was done manually and slow. To obtain qualitative signal of frequency the vibrating wire sensor was placed inside a box to avoid the air convection noise impacts on the frequency stability (this box is not shown in Fig. 3). The box had small diaphragm for laser beam. The laser and photodiode were placed on the same board with possibility of the adjustment when laser and photodiode axis's crossed on the wire.

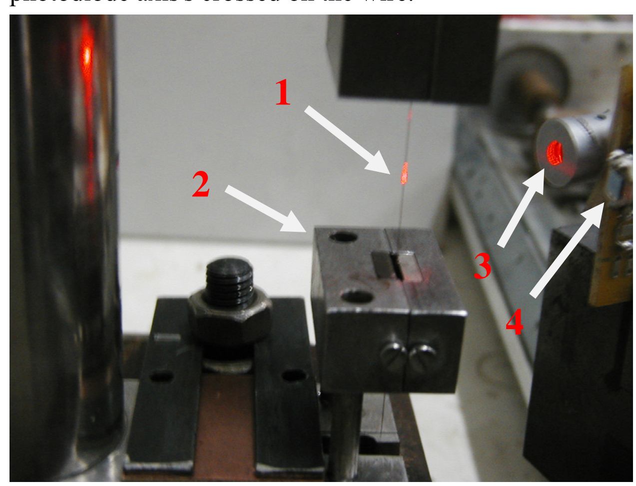

Figure 3: Layout of experiment: 1 - vibrating wire of VWM with wire length 80 mm, 2 - wire oscillation generating magnet poles, 3 - laser, 4 - photodiode.

As remarked above because of 50 Hz indoor lighting the signal from photodiode had 50 Hz modulation. When wire started to oscillate the signal split on the two levels (see Fig. 4).

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPME076

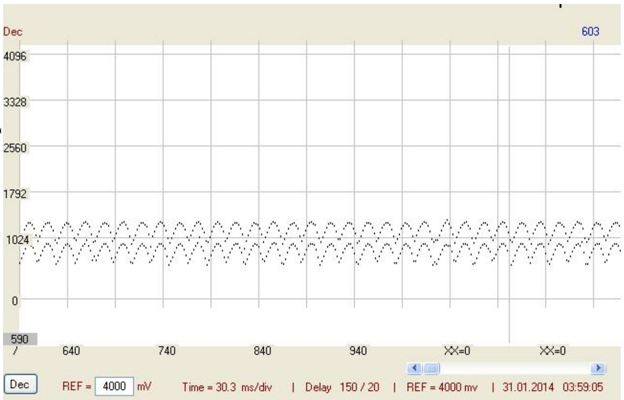

Figure 4: Typical split of 50 Hz lightening background: upper line - signal of photon scattering when wire is at high density area of laser beam and bottom line - at lower density.

At this experiment, the vibrating wire sensor was feed manually with low speed, which allowed photodiode measurements to be adequate to beam density frequency signal. The complete scan on distance about 5 mm backward and forward is presented in Fig. 5.

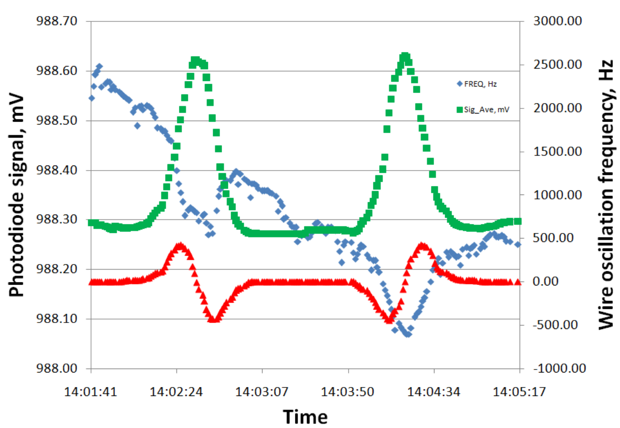

Figure 5: Forward and backward scan of the vibrating wire sensor. Red line - differential signal from photodiode at ultimate positions of wires during oscillations. Green line - averaged signal of 1000 measurements of photodiode at ultimate positions of wires, Blue line - vibrating wire oscillation frequency also depends on reflecting on wire photon numbers.

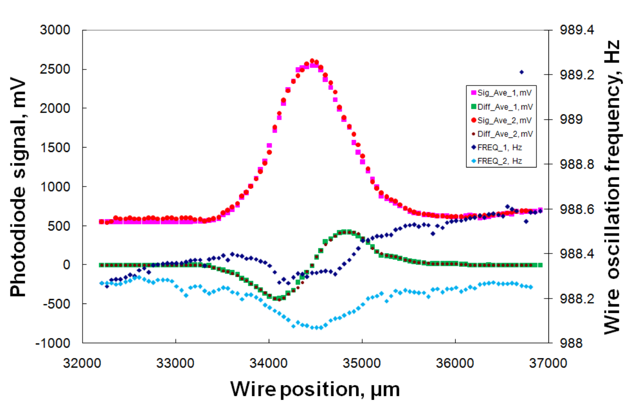

Figure 6: Scan of laser beam as function of oscillating wire position. Red and magenta lines - averaged absolute signal from photodiode (forward and backward scan), green and brown lines - differential signal from photodiode (forward and backward scan), dark blue and light blue lines - frequency signal (forward and backward).

Spatial overlapping of scan process is presented in Fig. 6. One can see that the signals from photodiode (averaged absolute and differential) practically coincide. In case of frequency signal we obtain significantly more difference because of the thermal drifts of the wire and the presence of noisy atmosphere.

DISCUSSION

Proposed new method of using oscillating wire as a target seems to be interesting improvement of the traditional wire scanners technique. Performed first experiments using laser beam showed that the idea can be realized with very simple instruments. New investigations at more fast measurements are planned.

ACKNOWLEDGMENTS

Authors are grateful to J. Bergoz for very necessary support. We would also like to thank G. Harutyunyan and M. Chung for interest and friendly help in the paper design.

REFERENCES

[1] K. Wittenburg, “BEAM HALO AND BUNCH PURITY MONITORING”, CERN Accelerator School 2009-005, p. 557, (2009).

[2] K. Wittenburg, “OVERVIEW OF RECENT HALO DIAGNOSIS AND NON-DESTRUCTIVE BEAM PROFILE MONITORING”, Proceedings of 39th ICFA Advanced Beam Dynamics Workshop, High Intensity High Brightness Hadron Beams, HB’2006, Tsukuba, Japan, p. 54, (2006).

[3] S.G. Arutunian, “Vibrating wire sensors for beam instrumentation”, Beam Instrumentation Workshop, BIW08, (May, 2008, Lake Tahoe, USA) and cited.

[4] S.G. Arutunian, M.R. Mailian, K. Wittenburg, “VIBRATING WIRES FOR BEAM DIAGNOSTICS”, Nuclear Instruments and Methods in Physics Research. Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, v. 572, pp.1022-1032, (2007).

[5] G. Decker, S. Arutunian, M. Mailian, G. Rosenbaum, “First vibrating wire monitor measurements of a hard x-ray undulator beam at the Advanced Photon Source”, Proceedings of DIPAC 2007, Venice, Italy, pp. 36-38.