PARTICLE AND PHOTON BEAM MEASUREMENTS BASED ON VIBRATING WIRE

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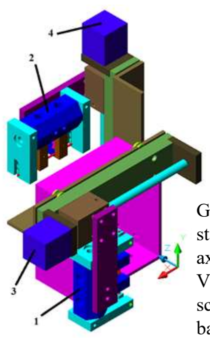
Abstract

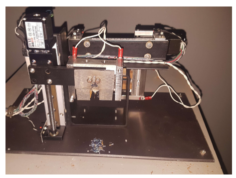
The instrumentation introduced herein is based on high-quality vibrating wire resonator, in which the excitation of wire oscillation is made through the interaction of the wire current with a permanent magnetic field. The high sensitivity of the oscillation frequency to the wire temperature allows the resonator to be used for measuring charged-particle/X-ray/laser/neutron beam profiles with wide dynamic range. The beam flux falling on the wire increases its temperature from fractions of mK to hundreds of degrees. Another application method is to use the vibrating wire as a moving target, in which signals created at beam interaction with the wire are measured synchronously with the wire oscillation frequency. This method allows to effectively separate the background signals. Also, the well-defined (in space) and stable (in time) form of the wire oscillation allows the vibrating wire to be used directly as a miniature scanner for measuring thin beams. The latter two methods enable a significant reduction in scanning time compared to the original thermal-based method.

THERMAL METHOD

The Vibrating Wire Monitor (VWM) on the thermal principle can be described as a wire stretched between two clips mounted on the basis. Part of the wire is placed in a magnetic field created by permanent magnets. The oscillations of the wire at natural frequency are excited by the interaction of the current flowing through the wire with the magnetic field. The wire is introduced to the input of operational amplifier with positive feedback, which leads to autogeneration of natural oscillations of the wire.

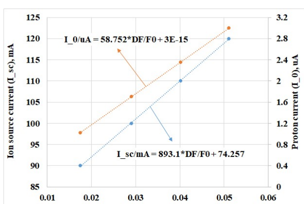


General view of the station along the beam axis. In the foreground VWM2 (vertical scanning), in the background VWM1 and vacuum window.

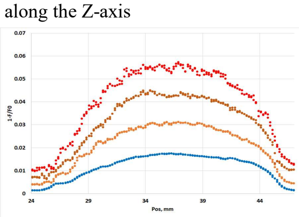


View of the vertical scan monitor after the end of the experiment. It can be seen that the protective lead plate melted when scanning to a great depth, however, the sensor remained functional

Profiling station for horizontal and vertical scanning, equipped with VWMs (1 and 2) and linear drive systems (3 and 4).). Beam extends along the Z-axis



Dependences of ion source current and proton current on distribution's maximal values



Vertical beam profiles for different beam current values. Bottom-up ion source current corresponds to : 90 mA, 100 mA, 110 mA. 120 mA

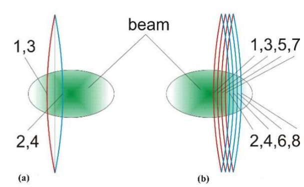
Communication between the experimental room and the control room functioned by means of 50 m long LAN-cables. Both monitors showed performance under fairly severe conditions of overheating of the protective lead plates.

VWM FOR ELASTIC PROPERTIES INVESTIGATION

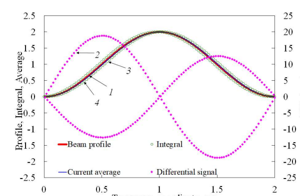
VMWs can also be applied for measuring neutron fluxes penetrating the wire. It is proposed to use a vibrating wire exposed in the neutron flux, to observe the effect of neutron irradiation impact on the elastic properties of metals. The effect is caused by both neutron capture (mainly for neutrons with energy less than 1 MeV) and lattice disturbance during the atom-neutron collisions with energy more than 1 MeV. We suggest to use a two-wire monitor, in which wires are located in the same thermal space and are separated to significantly differentiate the exposure of neutrons to the wires. For preliminary estimations of the effect we use the data of [Neutron irradiation effects on the mechanical properties of HY-80 steel, W.F.Nold, Pennsylvania State University, 1986] in which experimental results on the impact of fast neutron fluence of Pennsylvania State University's Breazeale Reactor on mechanical properties of HY-80 steel was investigated. In particular, the change in the yield strength of samples was measured by an integral fluence about 5E+17 n/cm2 with the change of yield strength value by 4.75%. The typical frequency resolution value of the VWM is 0.01 Hz/7000 Hz = 1.4E-4 %. Using the above experimental data on the effect of neutron fluxes on the mechanical properties of the wire and this VWM characteristic, we obtain the following monitor resolution value on neutron fluence: 1.5E+13 n/cm2.

VW AS RESONANCE TARGET

It is often necessary to produce a faster scanning of the beam. For this we proposed a hybrid method based on measurement of secondary particles during beam scattering on a wire (traditional Wire scanners), but using a vibrating wire as a target. Synchronous measurements with wire oscillations allow detecting only the signal generating from the scattering of the beam on the wire. This resonant method enables fast beam profiling in the presence of a high level of background. The method can be applied to different types of beams by simply choosing an appropriate detector for each case. For photon beams, fast photodiodes can be used, and for charged particles, scintillators combined with photomultipliers etc.



Odd indices the wire at its leftmost position, even indices the wire at its rightmost position: (a) the scanner is stationary, (b) the scanner is moving..

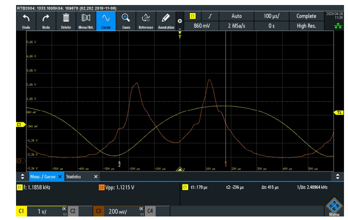


1 - initial profile, 2 - differentiation of synchronized signal, 3 - integral of differential signal with sign inversing, 4 - current average of 3 practically recover initial profile 1...

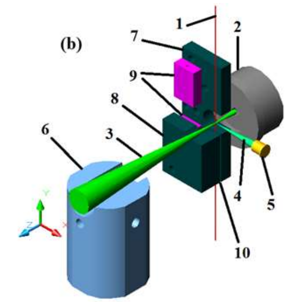
For a certain data processing algorithm, the scanning speed can significantly exceed the speed of the wire during its oscillations. The algorithm is as follows: a differential signal on the extreme positions of the vibrating wire is calculated, this signal is integrated (with inversion of the sign on the half-periods of wire oscillation) and then the current average procedure is applied to it. An example of using such an algorithm is shown - here the speed of scanning is 10 times higher than the average speed of the wire on one half-period of oscillations. The method was successfully tested in the laser beam tomography experiment.

VW AS A MINIATURE SCANNER

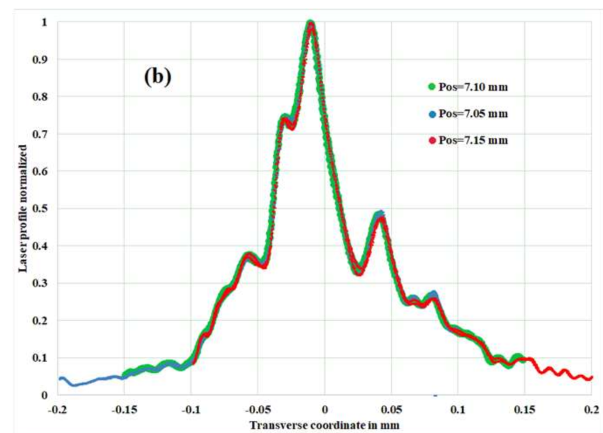
The amplitude of vibrations of the developed resonators of the vibrating wire reaches a few hundred micrometers. Such a range of wire motion is well suited for profiling micrometer-size beams.



One measuring period for the 7.15 mm position with high resolution option of RTB2004: signal from the wire (yellow), signal from photodiode (orange). The measurements were made in the averaging mode with 2.5 GSa/s, which in the high resolution option were averaged by the time period of 500 ns.



Optical layout of the experiment: wire (1), lens (2), focused laser beam (3), reflected photons (4), photodiode (5), support of (only the bottom half is shown) (6), first magnetic pole (7), second magnetic pole (8), and permanent magnets (9). The magnetic field is confined between the magnetic poles (10)



Scanning of the profile in several positions of the vibrating wire monitor allowed us to restore the profile of the beam in absolute coordinates. The method of determining the laser beam profile by superimposing the overlapping profiles in several resonator positions of the vibrating wire is similar to the creation of a panoramic image by stitching procedure. This procedure allows to separate the structure inherent to the profile (an analogue of panorama) from that associated with the uncertainty of the wire movements (similar to camera defect).