BEAM SCANNER FOR THE OXFORD ELECTROSTATIC TANDEM ACCELERATOR

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Detailed description of a new design used at Oxford for scanning the beam profile is given. The main drawback of some other beam scanners of having rotating components and bearings in vacuum is eliminated. The electromagnetically driven wire vibrates at 20 c/sec and crosses the beam parallel to X and Y axes. The simplicity and small size makes possible its use anywhere on the beam lines. The display unit which is centrally placed in the control room can be switched to any beam scanner so the operator can check the condition of the beam at all the important points. Circuit diagrams for the driver, head amplifier and also the display unit are given. Test results obtained on the Oxford Tandem Accelerator are presented.

Introduction

Ever since particle accelerators appeared on the scene of Nuclear Physics there has been a demand for a device which would be able to detect the size, shape, position and intensity of the beam reliably without permanently interrupting the path of the particles. There are several devices developed for this purpose although all of them suffer from limitations. All those considered have one thing in common and that is a thin wire or wires scanning the beam. In some cases however, the wires scanning the beam interrupt in different planes which causes screening effect, secondary collection and gives false pictures of the beam cross section. In all cases auxiliary devices are required to keep the wires out of the beam when the scanner comes to stop or when it is not in use.

In Oxford where a 24 MeV Accelerator is being constructed it has been decided not to use any of the existing beam scanners but design a new kind based upon the principle invented at the Atomic Energy Research Establishment, Harwell. This is free of the limitations mentioned, simple in construction and requires very little maintenance.

The mechanical scanner

Two requirements guided us in the mechanical design. The first one was the elimination of such components as bearings in vacuum, rotary vacuum seals and slip-rings which can be a source of electrical noise. The second requirement was the elimination of the multi-wire system and its associated multi-plane-scanning.

The Oxford beam scanner is basically a mechanical vibrator driven by electromagnetic means. The vibrating spring with the scanning wire attached to it is shown in fig.1.a. The wire assembly is positioned at 45° to the vertical and in this way one side of the wire scans the beam horizontally while the other does the same vertically. The nominal stroke is 3.5 cm and the maximum beam diameter which can be scanned is 2.5 cm. The spring is made of steel heat-treated at 900°C and tempered at 450°C and the wire of 0.012" tungsten jig-annealed at 750°C for $\frac{3}{4}$ hour in vacuo. The wire is fixed to the spring by hard soldering. The assembly has a sharp mechanical resonance around 20 c/sec and this resonance is used to make the wire sweep across the beam.

The movement of the wire is detected by a piezo-electric tranducer which forms a vital link in the loop between the mechanical vibrator and the driver circuit. The size of the transducer is 1 1/16" x 0.063" x 0.026" and it is coupled to the spring via a pivot set into a jewel on the end of the transducer. The whole mechanism is assembled on a dural flange and housed in a light alloy casting. The driving of the wire is done by magnetic polepieces through the flange and energised by a coil outside the vacuum.

The block diagram, the assembly and casting are shown in fig.1.b. 2. and 3. respectively.

Driver circuit

The driving coil is powered by a transistorised circuit shown in fig.4.

Starting up is achieved by the free-running multivibrator formed by TR_4 and TR_5 whose repetition frequency is tuned by RV_2 close to the resonant frequency of the wire. This signal is amplified and fed into the power transistor TR_8 which energises the driving coil in its emitter. As soon as the spring starts moving the signal generated by the transducer locks the multivibrator. The use of a multivibrator in this way eliminates the change in the amplitude of the swing of the wire with the ageing of the transducer. The transistors TR_2 and TR_3 form a buffer circuit between the transducer and the multivibrator. The potentiometer RV_3 is for setting the stroke of the wire. The driver unit also contains a filter amplifier with phase adjusting circuit, which provides X sweep for the display unit.

In order to determine the position of the beam relative to the geometric centre of the flight tube, synchronising pulses are used on the screens of the display tubes. These are derived by a light source and a photo transistor TR_{14} placed on the opposite side of the housing. The wire is designed in such a way that when it crosses the centre of the beam line its straight part near the spring intercepts the light beam shining through the two circular windows placed on opposite sides of the casting.

The pulses obtained in this way are amplified, shaped and finally fed into the grid circuits of the CRTs. On the screen they appear bright spots. The circuit is shown in fig. 5.

Signal amplifier

The signal picked up by the wire is passed to a head amplifier of high input impedance. In the first stage a field effect transistor is used to reduce the chance of the first stage being damaged by nuclear radiation. Since the imput impedance of the amplifier is much greater than the wire load resistors, the load on the wire and also the input signal to the head amplifier is entirely determined by the resistors. The appropriate value can be selected remotely by the use of a Ledex switch. From the head amplifier the signal is fed into the plate amplifiers of the display unit. The circuit of the head amplifier is shown in fig.6.

Display unit

For displaying the beam profiles two double beam CRTs are used. The two pulses representing the cross section of the beam in X and Y directions are displayed separately on the screens of the two CRTs. The second beams of the CRTs are used for displaying the positioning pulses. When the phase is correctly set and the display is calibrated only one bright spot appears on the screen of each CRT. The size of the beam can be read in mms from the horizontal graticule. The momentary current of the beam is measured on the vertical scale calibrated in μA/cm. The plate amplifiers, capable of delivering 400 V peak to peak for horizontal and vertical deflection, are identical and fully transistorised. The circuit of one plate amplifier is shown in fig.7. One display unit serves six beam scanners and the operator can select and display any one.

The six drive circuits and the two plate amplifiers are wired on the same size boards. These all form part of the control unit as plug-in subunits.

Test and results

All the scanner assemblies are tested for accuracy before installation. The test consists of two parts. First the wire is tested for distortion in its stationary position and at full amplitude. The test is carried out by optical means. When the distortion of the wire is within acceptable limits the distance between the signal and reference peaks in either the X or Y axes are 0.5 mm max apart, at magnification of 2. This represents 1% error.

The symmetry of the stroke is checked in a perspex chamber by the use of a well focussed light beam and a photo transistor fixed to the same carriage. The carriage is adjustable along the X and Y axes and the position of the light beam can be read from the X and Y scales. With this arrangement the shape and position of the wire can be mapped at any amplitude. All of these tests are made relative to the fixed reference light beam.

The displayed interval between the mapping pulse and the reference pulse is proportional to the displacement of the mapping light beam from its central position, within the reading error of the displays.

The photograph in fig.8. was taken of a beam as displayed on the screen of the CRT.

References

1. Patent Application No.28791/63 A.E.R.E. Harwell.
2. P. H. Rose, The three-stage tandem accelrator, Nuclear Instruments and Methods 11(1961) No1.
3. G. Hortig. A beam scanner for two dimensional scanning with one rotating wire. Nuclear Instruments and Methods. 30(1964)No.2.
4. Beam Profile Monitor. Equipment Specification No.A-1200. High Voltage Engineering Corporation.

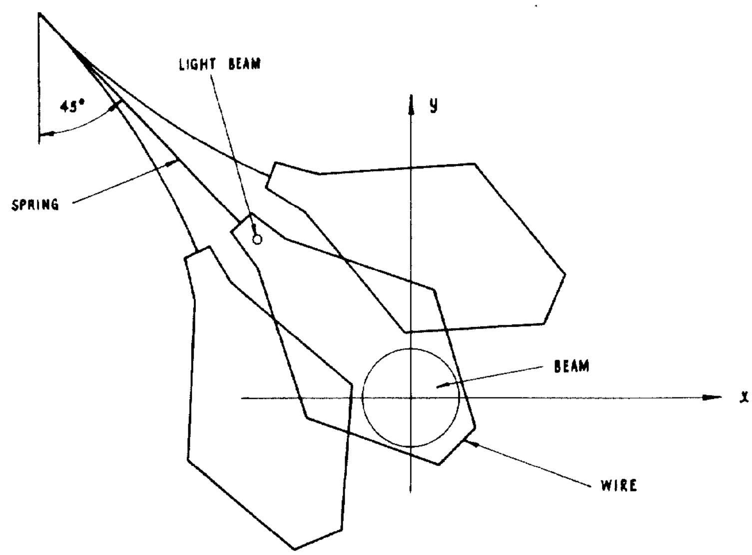


Fig. 1a. Wire assembly.

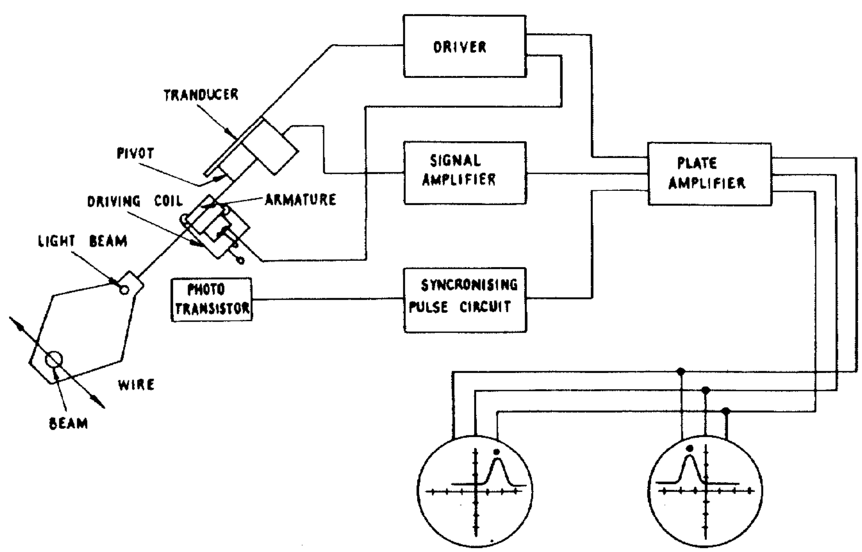


Fig. 1b. Schematic diagram of the beam scanner.

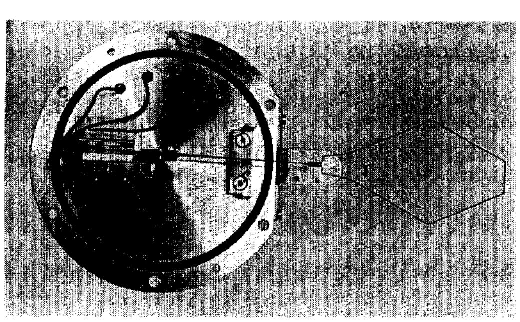


Fig. 2. Scanner assembly.

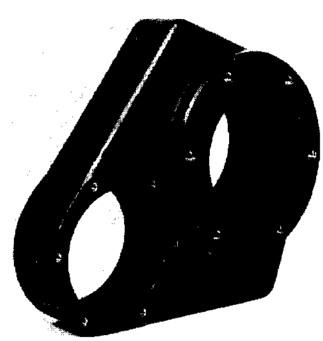


Fig. 3. Casting.

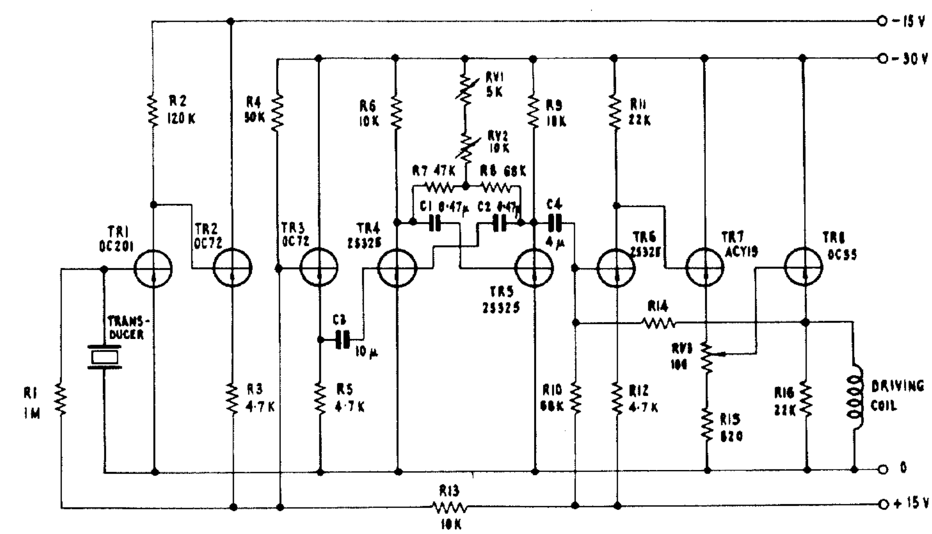


Fig. 4. Driving circuit.

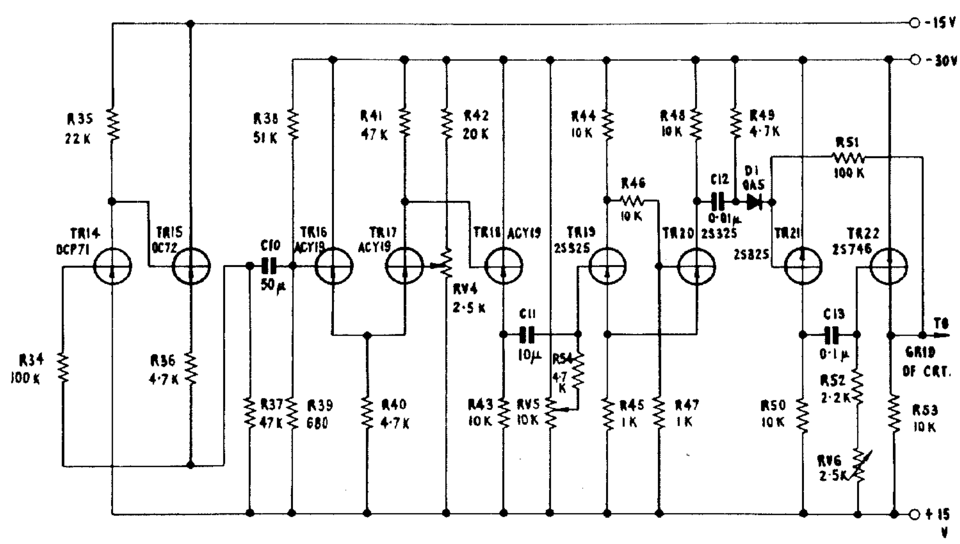


Fig. 5. Syncronising pulse circuit.

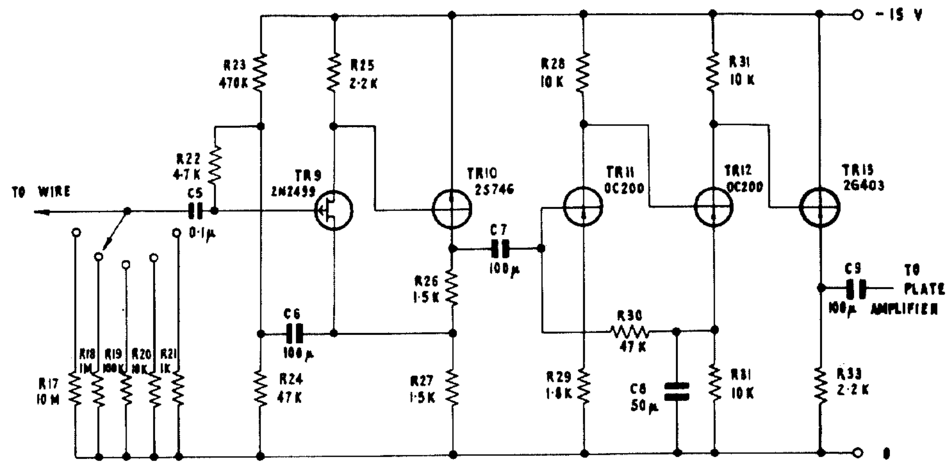


Fig. 6. Signal amplifier.

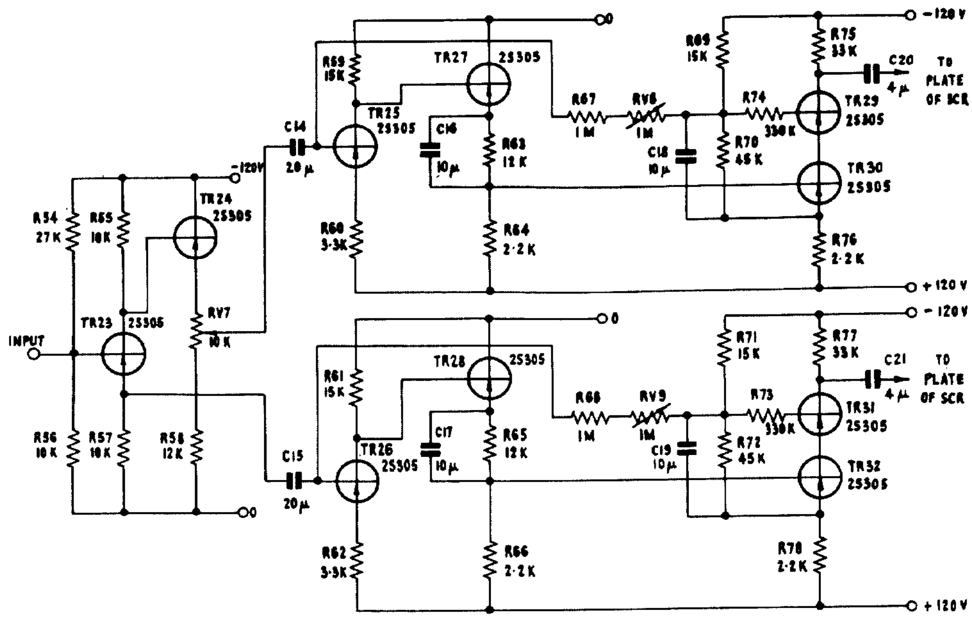
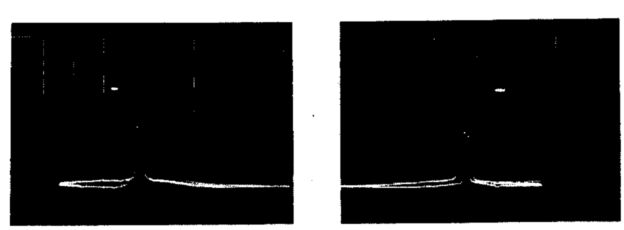


Fig. 7. Plate amplifier.



X display Y display

Horizontal magnification:1
Vertical scale: $2.5 \cdot 10^{-7}$ A/cm
Displacement: 8 mm left
11 mm up

Fig. 8. Beam profile.