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N.P.L. MEKOMETER III

by

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1. Introduction

1.1 The N.P.L. Mekometer III is basically very similar in method of operation to the Mekometer II already described elsewhere.[1] The measuring process consists of determining the phase of modulated light returned from a reflector (placed at one end of the line to be measured) back to the instrument. Elliptical polarisation modulation is used so that linear electro-optic crystals of the ADP or KDP type may be used for both modulation and de-modulation. In order to be suitable for the measurement of large nuclear machines, the resolution 0.0003 ft. has been improved to be approximately (0.1 mm) under good conditions at distances up to 3000 ft. (1 km). The maximum expected range is 10000 ft. (3 km). Nevertheless, the principal objective remains to produce a very simple measuring instrument for commercial exploitation. The volume and weight of Mekometer III is one-half that of the predecessor. The instrument and power unit each weigh 5.5 kg (12 lbs.).

1.2 Other significant changes include the use of two (or possibly four) potassium dihydrogen phosphate (KDP) crystals. This dual system eliminates scattering from the transmitted light beam into the receiving photodetector. The distance required is obtained on a simple decimal read-out system requiring no computations.

2. The Apparatus

2.1 Fig. 1 shows a diagram of the new arrangement. The KDP crystals are arranged, at the high impedance end of a quarter-wave coaxial cavity resonator. The optic axes (Z axes) of the crystals are parallel to the electric field in the cavity. This modulating cavity is excited into strong oscillations at frequencies near to 500 MHz for a duration of 40μs by pulsing the ceramic disc-seal triode valve shown. It develops several thousand volts of modulating field across each crystal.

2.2 Light from a xenon flash-tube is first plane-polarized and then passed through a KDP crystal from which it emerges elliptically polarized at the modulation frequency. This beam is imaged down by a short focal length lens at the focus of the main 60 mm diameter objective, thereby transmitting a beam about 1.5 milliradians in diameter.

2.3 The reflector, placed at the far end of the line to be measured, may be of either the "cat's eye" or cube-corner type. At the instrument returned light is deflected sideways, by a plane mirror placed in front of the main objective, into the variable light-path shown. After traversing this phase-shifter, the returned light is passed through the second KDP crystal and thence to the photomultiplier. Between this second KDP crystal and the photodetector the second polarizer crossed relative to the first. Thus the intensity of light reaching the photomultiplier is a measure of the degree of ellipticity of polarization left after passage through the KDP crystal and this, in turn, depends upon the modulation phase of the light from the distant reflector.

2.4 The position of the movable element of the variable light path is accurately and directly measured by a graduated steel tape running over a drum geared to the read-out dials. These dials are used only for obtaining the integer number of modulation half-waves in the required distance, the excess fraction being obtained from the tape. For a measurement, the variable path is first adjusted to a minimum of the photodetector output as indicated on the phase-meter. Once this position has been approximately located, accurate positioning is achieved by an FM switch which introduces a small symmetrical deviation of the modulating frequency between alternate pulses of light and operates the detector synchronously so that the minimum now appears on the phase-meter as a centre-zero null.

2.5 The effect of atmospheric refractive index is eliminated in substantially the same manner as for the Mekometer II. The modulation wavelength is determined from the resonance of a cavity resonator filled with dry air at the ambient atmospheric pressure and aspirated externally so as to acquire quickly the prevailing temperature. A single small fixed resonator operating at nine times (4.4GHz) the fundamental modulating frequency is used. This is a coaxial-line resonator entirely constructed of plated fused quartz.

2.6 The step-recovery diode harmonic generator can also be used to multiply by ten times, so that in this case the modulating frequency has a value of nine-tenths the fundamental value and this value is used to obtain the 0-10 ft. intervals. The 0-100ft. and 0-1000ft. intervals are obtained by amplitude-modulating the multiplier (when in the X9 position) by quartz crystal derived frequencies which are 1% and 0.1% respectively of the fundamental. The modulating frequency is adjusted lower first by one and then by the other of these fractions so that the fixed standard cavity sees the upper sidebands caused by this amplitude modulation of the multiplier. Quartz crystal oscillators without temperature control are adequate for the production of these sidebands. Resonance of the standard cavity is displayed on the cavity meter in the same manner as the phase meter. The modulating cavity has a coarse and fine tuner consisting of an inner sliding cylinder producing up to 11% frequency shift.

2.7 The instrument can be mounted either on a standard theodolite tripod fitted with a centering base and optical plummet or removed from this for use on concrete survey pillars. Two eyepieces are provided for ease of setting-up. One views the area surrounding the target, the other shows the target illuminated by light from the transmitter. An elevation scale is provided which reads directly the slope to horizontal correction in parts per million, for deviations up to $\pm 3^\circ$.

3. Experimental Procedure

3.1 The observer makes the measurement as follows:-

After having positioned the instrument and reflector, he sets the modulating cavity to produce the fundamental standard modulation wavelength, (i.e. with the standard cavity frequency nine times this modulation frequency) and sets the variable light path for a detector minimum in the manner already described. The fraction of a foot in the required distance is then read off from the steel tape measure estimating (if required) to 0.0001ft. The pointers of the two read-out dials are then set to zero and the modulation frequency reduced to be one-tenth that of the standard cavity. The variable light path is again adjusted and the

0-10ft. rounding dial (B on Fig.1) read to the nearest wholse number and entered on the "unit" box on the data reduction sheet, Fig. 2. With the modulation wavelength set respectively 1% and 0.1% longer than the fundamental value (2 ft.) two more settings of the variable light path are made and the corresponding readings of the other read-out (C and D) dial drawn in as radial lines in the "tens" and "hundreds" boxes respectively.

3.2 If the required distance is not known to the nearest thousand feet, this rough measure is obtained from the unity count dial. This is operated manually and is used to change the modulation frequency a small amount in order to go from the photodetector minimum to an adjacent one, after the initial variable light path setting has been made. The reading of this dial is drawn in on the "thousands" box in Fig. 2. The distance is then obtained directly in the manner of reading a dial gas or electricity meter. For metric use the fundamental modulation length unit is 30 cms., the steel tape, of course, being divided in millimetres.

4. Preliminary Results

4.1 At the time of writing the instrument has not been fully tested but the following sensitivities have been observed:

RANGE		SENSITIVITY	
ft.	m.	ft.	mm.
30	10	± 0.0003	± 0.10
160	50	± 0.0002	± 0.05
* 2300	700	± 0.0003	± 0.10

* cloudy daylight conditions

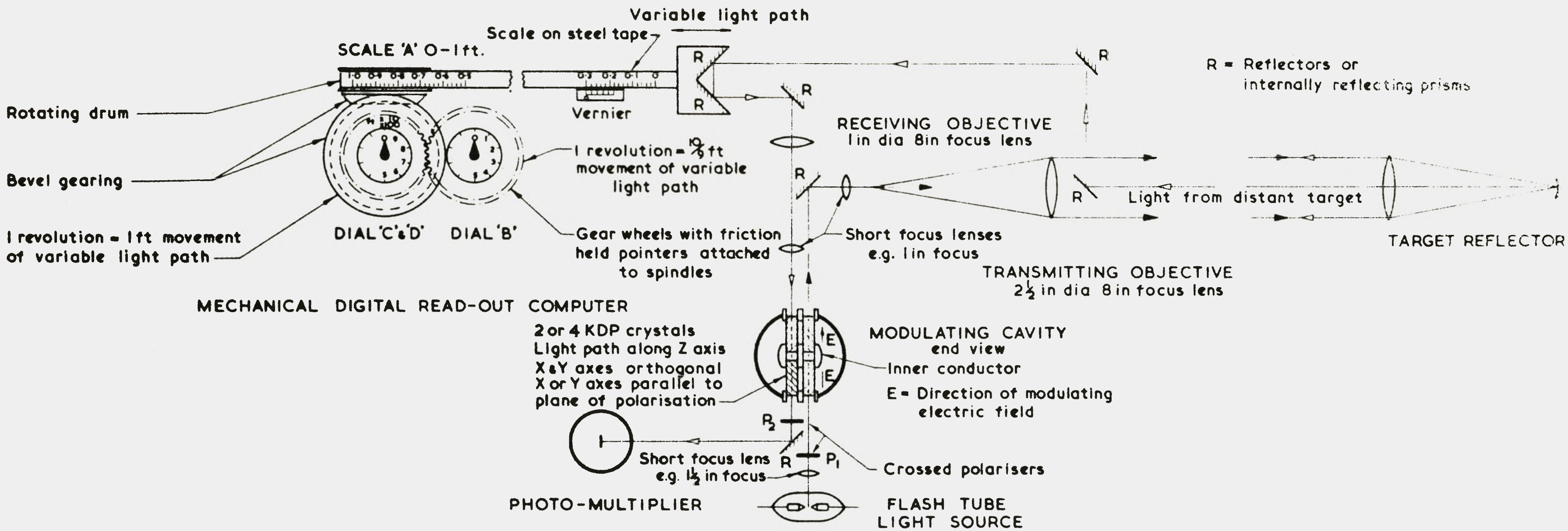
TABLE 1

4.2 These observations have been made with a single reflector of 5 cm effective diameter, and using the frequency modulated (FM) null setting on the phase meter. It is expected that the cyclic errors of phase present in the variable light path will be very small as theory shows the Mekometer to be free from such errors. In practice, with the Mekometer II no cyclic phase error could be found to within the reading accuracy of the scale, namely ± 0.0005ft. (± 0.15mm.). Makometer III should be considerably better than this as the movement of the internal variable reflecting element is more accurately determined..

4.3 Fig. 3 is a photograph showing the tripod-mounted Mekometer III with Mekometer II on the N-end of the NPL 300 metre base.

REFERENCES

1. Froome, K.D. and Bradsell, R.H., 1966, J.Sci.Instrum., 43, 129-33.



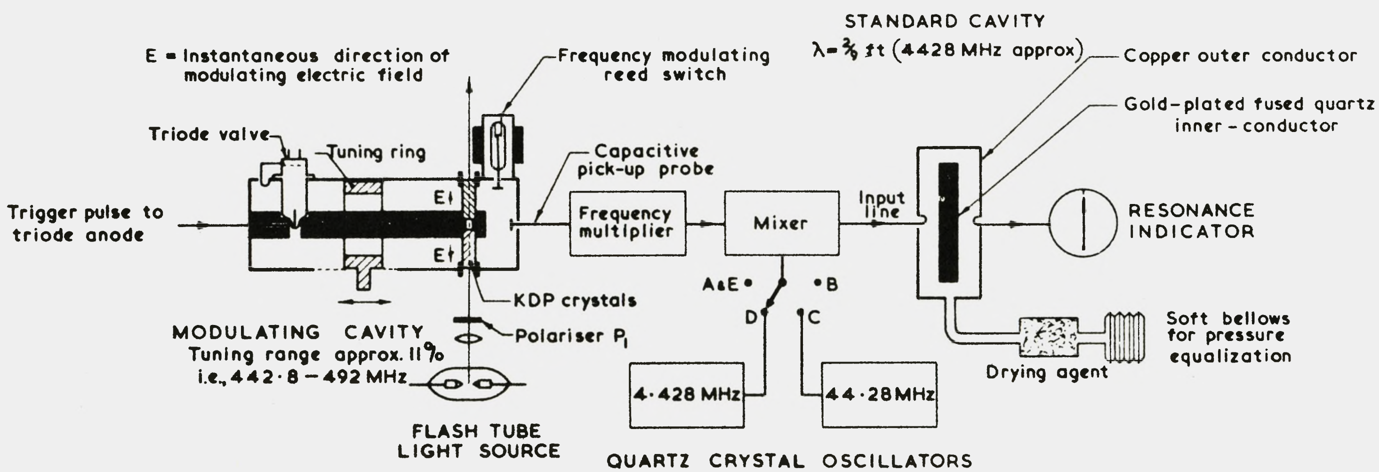


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Fig. 1

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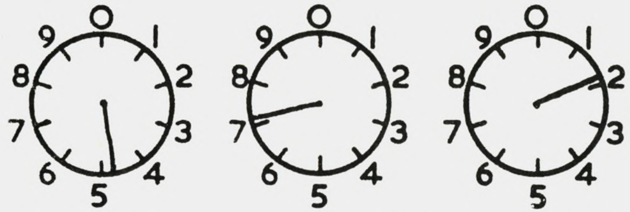
MEKOMETER III Data reduction sheet (Ft)

Thousands Hundreds Tens Units



9

Fraction.

0·2163
·2166
·2160
2163

Total units : 4719

D = 4719 ·2163 ft

Reflector = — 3 ·0000 ft

Total corrections = · ft

Elevation of target :

Result 4716 ·2163 ft

Corrections :

Altitude : Nil

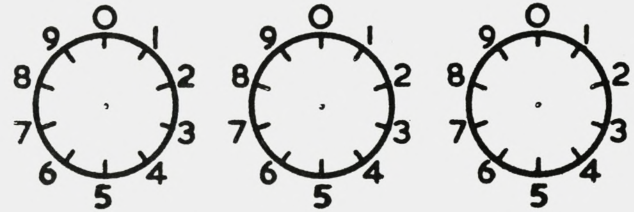
Slope : Nil

Date : 18/8/67

Remarks :

MEKOMETER III Data reduction sheet (Metric)

Thousands Hundreds Tens Units



Fraction. (cm)

Total units :

x 30 = cm

Mean fraction = · cm

D = · cm

Reflector = · cm

Total corrections = · cm

Elevation of target :

Result { · cm
· met

Corrections :

Altitude :

Slope :

Date :

Remarks :