This calendar

Electronic distance meters mean that the survey engineer is now faced with a number of physical fundamentals, which were, up to now, only current to electronic engineers. We should like with this calendar to present a number of these fundamentals in words and in pictures and show the three Kern electronic distance meters in their typical application. The basis of electronic distance measurement is the formula

$$\lambda = \frac{c}{n \cdot f}$$

λ Wavelength (in m)
c Velocity of electromagnetic waves in vacua (in m sec^{-1})
n Index of refraction of electromagnetic waves in the medium (nondimensional)
f Frequency (in sec^{-1})

The units of measurement in the above expression, the second and the metre, have been recommended on the basis of physical research by the General Conference for Weights and Measures and have been given binding force by the individual countries within the area of their sovereignty. This facilitates comparisons of measurement data and, by an adequate precision of the definition, ensures the reproducibility of units of measurement, essential in physics.
The only two numerically defined units of measurement, involved in electronic distance measurement, are the second and the metre. In addition the mechanism of operation of the electronic distance meter involves a wide variety of fundamentals, which are either rigorously defined in physical terms or differentiated with sufficient accuracy technically, e. g. in the form of a module. This range of fundamentals will emerge from each short description of the functioning of the equipment.
Electronic distance meters used in survey work, operate on the *phase comparison process*. An *electromagnetic wave* is used as the carrier of *signals* and may, therefore, be designated the *carrier wave*. Two groups of electronic distance meters can be distinguished on the basis of the *wavelength* of the carrier wave, *microwave instruments* with wavelengths between a few millimetres and a few centimetres and *electro-optical instruments* with wavelengths from 0.3 to 1 μm. In microwave instruments a *klystron* is used as a *carrier wave generator* and in electro-optical instruments a suitable *light source*. Variations in the *amplitude* or *frequency* are regarded as signals. In the phase comparison processes an oscillator, the principal component of which is an oscillating quartz crystal, controls at a constant frequency, adjusted to a required value, a *modulator* which varies periodically the amplitude or frequency of the carrier wave. This produces a modulated wave, the so-called *modulation wave*. The length of the modulation wave is obtained from the *velocity of the carrier wave* and the frequency of the oscillator. A *transmitter*, incorporated in the electronic distance meter, emits as high as possible a *power* in the form of a modulated carrier wave in the direction of a *reflector* set up in the target. After *reflection* the modulated carrier wave returns with a portion of the emitted power to the *receiver* in the distance meter. The distance between distance meter and reflector is determined from the *phase difference* between the emitted and received modulation wave and from the modulation wavelength. The phase difference is determined in the *phase measuring part* in the distance meter, which requires a minimum received power, i.e. a minimum *signal strength*.
Six fundamentals of importance for electro-optical distance measurement are represented by symbols in the calendar illustrations. The remaining illustrations show, with one exception, the current models of Kern electronic distance meters and a prototype of the Mekometer. The one exception in the series of electronic instruments is the Kern DK-RT double-image tachymeter, which in the course of years has become almost the symbol of a survey method, the polar coordinate method. Double-image tachymetry will become less important in the future, but will not disappear altogether, in view of the considerable experience with the instruments and their low susceptibility to failure.

Cover:
In order to determine the length of the rim for a wooden wheel, the wheelwright places a simple measuring disc on the rim of the wheel and runs it round the circumference. He counts the total number of rotations of the disc and marks the point at which the measuring disc returns to its original position. Then he rolls the measuring disc the same distance, this time over the flat iron sheet which is to form the rim.
By this means the craftsman determines the length of the rim without having recourse to units of measurement or calculations. This example, in conjunction with the contents of this calendar, may provide an indication of the development and variety of measuring techniques

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The Unit of Time, the Second

Measurement of the speed of light requires the definition of a unit of time and a unit of path travelled. The unit of time is the second.

The characteristic feature of time is that it cannot be represented by a material quantity, but only by a periodic process. The accuracy of the definition of time is thus a function of the accuracy of the periodic process defining the unit of time. One of the most important tasks of time measurement is, therefore, the search for accurate periodic processes.

The concept of time in daily life is bound up with the daily course of the sun and the annual passage of the earth round the sun. The rotation of the earth round its axis and a part of its trajectory round the sun yields the unit of time "day" and the rotation of the earth round the sun, the unit of time "year". Since these units were too large to be appreciated, the attempt has been made since olden time to subdivide the day, as the most important unit of time, by periodic physical processes into units of hours, minutes and seconds, which stand in simple numerical ratios to each other. Clocks were constructed for this purpose. The principal functional group, which remained the most accurate up to the twentieth century, was that of pendulum clocks with the oscillation of a physical pendulum as the periodic process. In certain church towers and gate towers, pendulum clocks from the sixteenth century are still working today. An example of this is the clock in the Aarau upper tower which dates from the year 1532.

It was immediately apparent from the use of pendulum clocks that the daily zenith of the sun at a particular point on the surface of the earth was an insufficiently accurate periodic process, to define the duration of a complete day. It was even possible to show with pendulum clocks that the rotation of the earth round its axis represents a chronological dimension of only limited accuracy. The year as a periodic process has the disadvantage of not being a whole number multiple of the day. It has the advantage, on the other hand, of being capable of very exact astronomical definition. The International Committee for Weights and Measures therefore, decided, in 1956 on the following definition of time: "the second is defined as the fraction 1/31'556'925.9747 of the tropical year for 1900, January 0, 12 hours ephemeris."

This definition of time, although very accurate, is rather inconvenient, since the second as a unit of time is not at all times available.

The search for periodic processes revealed in the course of the twentieth century that electrical oscillations, stabilised by means of the piezoelectric effect of quartz, represent a very much more accurate measurement of time than pendulum clocks. These oscillations are technically very well suited for the division of the year, defined as the unit of time, into seconds.

Even more accurate periodic processes, reproducible at any time by a suitable apparatus, are available in the nuclear field. In this way, the second, defined as the unit of time, is permanently available. At the 13th General Conference on Weights and Measures 1967, the following resolution was passed: "The second is the duration of 9'129'631'770 periods of the radiation, corresponding to the transition between the two hyperfine levels of the ground state of caesium-133."

Church tower in Villigen (Aargau)

Januar 1975 - 2014

Sonntag		5	12	19	26
Montag		6	13	20	27
Dienstag		7	14	21	28
Mittwoch	1	8	15	22	29
Donnerstag	2	9	16	23	30
Freitag	3	10	17	24	31
Samstag	4	11	18	25	

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The Stabilization of the Oscillator Frequency in Electronic Distance Meters

Everything would be a great deal simpler in the construction of geodetic instruments, if they were only used under exactly defined conditions. The greatest difficulty is caused by the ambient temperature of the instrument. This raises the question of the influence of various absolute temperatures and variations in temperature of the instrument during the measurements. This influence should not only be small, but if possible capable of being eliminated, or at least taken into account by means of known temperature-dependent calibration values. Theodolites are in this respect more advantageous than electronic distance meters, since the question of the calibration of the instrument does not arise, because the definition of the unit of angle can simply be given in purely mathematical terms.

One of the most important components of an electronic distance meter is the oscillator, which controls the modulation. Its frequency must remain constant over long periods of time and must be independent of the temperature, so that the measurement is obtained in the defined units of length. The constancy as a function of time at a constant temperature is simpler to achieve than the independence of temperature variations. The prevention of frequency variations of the oscillator as a consequence of temperature variations in the environment is possible either by thermostatic control or by network stabilization. Thermostatic control means that the working temperature of the oscillator is set outside the ambient temperatures occuring during operation and it is maintained by a thermostat by periodic heating to a constant temperature. Network stabilisation is understood to mean a skilful combination of components with temperature-dependent electrical characteristics, so that, within a particular temperature range the oscillator frequency remains constant within certain permissible limits.

The DM 2000 has a network-stabilised oscillator, which therefore oscillates at the correct frequency without any heating up time and independent of the temperature variations of the environment.

The principal field of application of the DM 2000 is in densificating the network of fixed points, as is necessary in particular for the execution of large building works. In this case, as in the example below, the necessary points are determined either by a triangulation combined with distances for establishment of the scale or by means of traverses with long sides. As a result of the variation in the requirement for angle measurement, depending on task and distance, the DM 2000 has not been fitted with an angular measuring part. It is thus open to the surveying enginer to use a theodolite of the required accuracy.

Densification of a fixed point network at Göschenen (Uri) with the electro-optical distance meter Kern DM 2000

Februar 1975 - 2014

Sonntag		2	9	16	23
Montag		3	10	17	24
Dienstag		4	11	18	25
Mittwoch		5	12	19	26
Donnerstag		6	13	20	27
Freitag		7	14	21	28
Samstag	1	8	15	22	

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Practical range, Distance and Directional Errors with Theodolites and Electronic Tachymeters

The Kern K1-S, a scale theodolite with direct reading of $1^c/0.5'$ and estimation of $0.2^c/0.1'$ is well suited, as a result of its convenient circle reading, as the carrier of an electronic tachymeter when short target ranges and not too strict accuracy requirements are involved. One-second theodolites are to be preferred, where the mean distance to the target is greater than about 200-300 m. The advantage resides not in the higher reading accuracy, but in the elimination of the influence of the circle eccentricity and of the axis play in measurements in one telescope position. In theodolites with only one circle reading position, for example in the K1-S, an unfavourable combination of the centring error of the circle and the play on the vertical axis can reach together 3 µm, which corresponds with a division radius of the horizontal circle of 45 mm at a target distance of 300 m to a lateral deviation of 20 mm. If the effects of directional and distance errors on the coordinates of the target point are not to exceed the same limiting values, the practical range of an electronic tachymeter on a theodolite with reading of one circle position is restricted to about 300 m. With lower accuracy requirements these limits can be extended. In the case of directional measurements with one-second theodolites the effects of directional errors will only become equivalent to the errors of the distance measurement at distances of about 600 m, as a result of the disappearance of systematic errors and also the higher reading accuracy.

The distance errors can be regarded over the whole range of electronic tachymetry as independent of the distance. At short distances it is often not necessary to apply a meteorological correction. The meteorological reference data for the DM 500 are +12°C and 1015 mb. In consequence, for air temperatures of —10°C to +34°C and an air pressure between 1100 and 930 mb meteorological corrections are not larger than $\pm 4.10^{-5}$ of the distance. This corresponds at 200 m to a maximum of ±8 mm.

A cadastral survey in a newly laid out vineyard area may, without any reservations, be carried out with a K1-S, especially since careful work with frequent control of the instrument orientation is quite as important as a high internal accuracy of the theodolite.

Cadastral survey in a vineyard at Fläsch (Grisons) with the Kern K1-S engineer's theodolite combined with the Kern DM 500 electro-optical distance meter

März 1975 - 2014

Sonntag		2	9	16	23	30
Montag		3	10	17	24	31
Dienstag		4	11	18	25	
Mittwoch		5	12	19	26	
Donnerstag		6	13	20	27	
Freitag		7	14	21	28	
Samstag	1	8	15	22	29	

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The Unit of Length, the Metre

The inscription on the stone reads: "IX hours from Berne."

The "hour" denotes the distance, covered on average by a pedestrian during one hour. The designation "road-hour" would be better in conformity with this unit of measurement than "hour" alone, since it indicates both a distance and also a time. The hour stones are not located at the same distances along the road as the present day mile stones in view of the dependence of speed on road conditions, but they were placed at equal intervals of time for a pedestrian. The road-hour as a unit of measurement suited the requirements of traffic on country roads up to the end of the nineteenth century. On the other hand, only a unit of measurement, which can be determined physically with sufficient accuracy, can be considered as a geodetic unit of length.

The principal purpose of the Swiss survey early in the nineteenth century was to prepare a 1:100'000 scale topographical map. Responsible for the work from 1832 to 1864 was General *W. H. Dufour,* to whom the finished map owed its popular name of the "Dufourkarte". Under Dufour's predecessor *L. Wurstemberger* the Commission for Land Survey at its first session in 1832 decided on the Toise as a unit of length for the land survey measurement of the time and gave the contract to *J. G. Oeri* in Zurich for the measuring equipment of the bases. Oeri produced four iron rods three Toises in length, the accuracy of which was provided by the transfer of a length, defined as a Toise. The Toise, like the metre which was introduced at the time, was determined by mechanical standards. Its magnitude could not be derived from a definition by means of an instrument, but could only be reduplicated by copying the standard. The Toise, which served as a base for the old Swiss base measurements, was a copy of an original known as the "Toise of Peru". It was produced by *Fortin* and kept in the Office of Linear Units of Measurement of the King of Denmark.

All mechanically defined standard lengths had the disadvantage up to the beginning of our century that their differences in length were only determinable by direct comparison. As soon as their lengths are expressed by constant parameters of a physical process, not only is an indirect comparison possible, but in addition the individual lengths can also be obtained at any time, independent of a mechanically given length. The "Comité Consultatif pour la Définition du Mètre", founded in 1953, recommended to the 11th General Conference for Weights and Measures 1960 a definition of the metre in light wavelengths, which was subsequently accepted. This definition runs: "The metre is defined as the fraction 1/1'650'763.73 of the wavelength of the radiation, propagated in a vacuum, emitted by atoms of the nuclide ^{86}Kr on the transition from the $5d_5$ to the $2p_{10}$ state." The corresponding spectral line has a wavelength of 0.6056 µm.

Old hour stone near Langenthal (Berne). The hour stones, which are still to be found today here and there on Swiss country roads, indicated to the pedestrian in earlier times the number of road-hours to the next large town

April 1975 - 2014

Sonntag		6	13	20	27
Montag		7	14	21	28
Dienstag	1	8	15	22	29
Mittwoch	2	9	16	23	30
Donnerstag	3	10	17	24	
Freitag	4	11	18	25	
Samstag	5	12	19	26	

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ME 3000 Mekometer, the Electro-optical Precision Distance Meter

The Mekometer is the precision instrument in electronic distance meters. The phase comparison error is ± 0.2 mm and the frequency error 10^{-6}. This gives a relative accuracy of the order of magnitude of millionths of the distance for measurement up to distances of a few hundred metres. At distances over 200 m the accuracy of the Mekometer is already superior to that of a one-second theodolite. The range of the instrument with three reflectors, each of 60 mm diameter, is about 3 km under good atmospheric conditions.

The Mekometer operates at a basic frequency of 500 MHz. This gives a half modulation wavelength of 30 cm. Four auxiliary frequencies enable the number of half modulation waves to be determined. Since each auxiliary frequency delivers one decade, a clear measurement is possible within 10,000 half modulation wavelengths, i.e. within 3 km. The measured phase angles are converted into metric units in a computer and indicated on a digital counter. The phase comparison is effected by means of a mechanically measurable variation in the light path. The accepted disadvantage of a non-automatic process is more than outweighed by the complete linearity of the phase comparison thus obtained, which is essential for a precision instrument. Repetition measurements to increase the accuracy can be carried out within a short period, using the basic frequency alone.

In spite of its high measurement accuracy, which is comparable with Invar wires, the Mekometer is largely insensitive to rough treatment during operation and transport. It is therefore suitable for all tasks, for which a relative accuracy over short distances is required. A great deal of work in the field of building supervision, precise layout, measurement of calibration bases, geology and geophysics and large-scale machinery construction can be made simpler with the Mekometer, if indeed such operations are possible at all without it.

Control measurement on a railway bridge at Camedo (Centovalli, Ticino), carried out with the Kern ME 3000 Mekometer

Mai 1975 - 2014

Sonntag		4	11	18	25
Montag		5	12	19	26
Dienstag		6	13	20	27
Mittwoch		7	14	21	28
Donnerstag	1	8	15	22	29
Freitag	2	9	16	23	30
Samstag	3	10	17	24	31

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Waves

The definition of a wave will be found in any physics manual: a wave is a temporal and spatial periodic disturbance of an equilibrium state. Waves can transmit energy and therefore signals. The principal parameters of a wave are the frequency and the phase velocity. The wavelength, which for the electronic distance meter is the most important parameter of a wave, is derived from the frequency and the phase velocity. The phase velocity is in most media frequency-independent. The property of a medium, that waves of different frequency are propagated at different speeds in it, is designated the dispersion.

Waves can be used for the measurement of distance, either by counting the number of wavelengths or on the other hand by measurement of the running time of the head wave between the end points of the sector for measurement. The first method gives rise to the interferometer, which makes use only of the property of the wave as a spatially periodic disturbance, so that its measurement values are a function only of the phase velocity and the frequency. The interferometer requires neither energy transport nor signal transmission. The second method forms the basis of electronic distance meters, in which the distance is determined from the running time of a signal. In consequence, the measurement value is a function of the signal velocity, i.e. of the velocity with which the energy is transported along the wave.

A signal is imprinted on a wave by modulation. Modulation denotes the variation in any properties of a wave. Modulation can be represented as a superimposition of sinusoidal oscillations of different frequencies. As a result of the dispersion of the transfer medium, the partial waves are propagated at different phase velocities. The velocity of a signal transmission can be determined by means of a Fourier synthesis from the individual phase velocities. A distance can be determined from the signal velocity and the running time of a signal. The two procedures currently used in distance measurement, the pulse procedure and the phase comparison procedure, do not differ in principle. It is only the type of modulation that is different. As a result of dispersion in the atmosphere, the phase velocity of non-modulated light waves at a wavelength of e.g. 0.56 µm as carrier wave are higher than the signal velocity by a factor of 1.000011.

Late snow at the Lake Golzern in Maderanertal (Uri)

Juni 1975 - 2014

Sonntag	1	8	15	22	29
Montag	2	9	16	23	30
Dienstag	3	10	17	24	
Mittwoch	4	11	18	25	
Donnerstag	5	12	19	26	
Freitag	6	13	20	27	
Samstag	7	14	21	28	

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The Kern DK-RT Self-reducing Double-image Tachymeter

One of the best known double-image tachymeters is the Kern DK-RT.

Double-image tachymetry started with the American *Richard*, who around the turn of the century placed a glass prism in front of a telescope objective and thus produced two superimposed pictures of a measuring rod. Since the displacement of the two images is proportional to the distance between prism and rod, the distance can be read off on a suitable rod graduation by using one image as a read-off index for the other.

These first double-image tachymeters did not meet with wide success. Although in principle high accuracies could be obtained, mixed images, oblique distance and interval estimation in the rod image represented serious impediments. The breakthrough only came after St. Gall geometer *R. Bosshardt* had created during the twenties in conjunction with the firm Carl Zeiss in Jena a tachymeter which incorporated the double-image distance measuring system in a state which has only been improved on in details today.

Apart from the complete separation of the superimposed images into two half images in mutual contact, the main step forward from the Richard apparatus consisted in the use of a rotating wedge pair after *Boscovic*, which varied by mechanical-optical means the effective wedge angle as a function of the cosine of the angle of elevation. It was possible in this way to measure a distance reduced to a horizontal plane, instead of the oblique distance; in the then state of computing technology that was an important advantage. In addition, an optical plane plate micrometer was placed in front of the telescope objective, which permitted measurement of the fractions of the division intervals between the rod image in the one image path and the read-off index in the other.

The first double-image tachymeters from the firm Kern were supplied in 1932. They were built on similar principles to the instruments of that time by Carl Zeiss in Jena.

The first DK-RT were supplied in 1950. Their design included the rectification of a number of inadequacies in existing instruments. For example, the range of the distance micrometer, up to then restricted to 20 cm, was extended to 100 cm. As a result the vernier on the rod was eliminated and with it a source of error. Less spectacular, but nonetheless pleasant, is the elimination of the distance correction for the slope-dependence of the addition constant. The variation in the addition constant could be reduced to negligible amounts by suitable dimensioning of the optical parts responsible for the image separation. In 1961 the DK-RT was given in the course of the last revision a new axis system and a new circle reading system.

The DK-RT represents in its present form the optimum achievable with conventional resources in terms of comfort and accuracy. In spite of electronic distance measurement, user experience on this instrument and its operating reliability will render it indispensable for years to come.

Even a survey team need a refresher now and then

Juli 1975 - 2014

Sonntag		6	13	20	27
Montag		7	14	21	28
Dienstag	1	8	15	22	29
Mittwoch	2	9	16	23	30
Donnerstag	3	10	17	24	31
Freitag	4	11	18	25	
Samstag	5	12	19	26	

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Reflection of Wave Surfaces

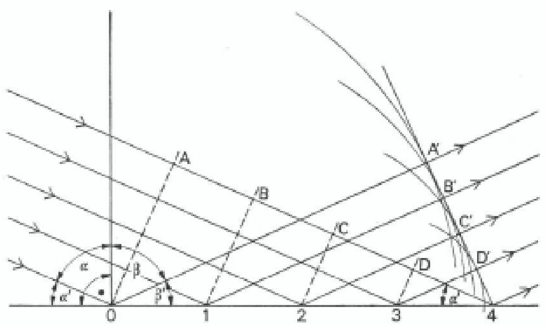
If light, which is an electromagnetic wave, strikes a boundary surface of two media, the wave is split: a partial wave proceeds in the second medium, while the other partial wave is thrown back into the first medium, i.e. reflected. However, the light is only reflected in a fully determined direction, if the boundary surfaces are not rough. This is the case, for example, with polished glass and metal surfaces. Glass reflects about 5% of the incident light from the air, it is "transparent"; smooth metal surfaces, on the other hand, reflect about 95% of the light, they are "opaque". At a rough boundary surface the light is reflected in disordered fashion in all directions (so-called scattered reflection). In the arguments below we will assume smooth boundary surfaces.

The law of reflection was known even to the Greeks. When *Huygens* set up his wave theory, he had therefore to verify the law of reflection. He found in the principle named after him an idea of genius: if we consider a spatial wave, any point which is struck by the wave, can then be considered as the point of origin of a new spherical wave. On this assumption, it is possible to explain in terms of wave theory not only the straight propagation of light, but also the laws of reflection and refraction and also diffraction phenomena.

For the sake of simplicity we will assume a flat wave, i.e. a wave with its centre of origin infinitely wide, the wave fronts being planes. In our drawing they are represented as straight lines 0 A, 1 B, 2 C, etc. The boundary surface will be assumed to be flat in the area where it is struck by the flat wave; let 0 4 be the line of intersection of the boundary surface with the plane of the drawing.

We represent in diagrammatic form the propagating wave by five straight lines ("rays"), which strike the boundary surface at 0, 1, 2, 3, 4. This is in no way intended to signify that the "rays" 0 and 4 limit the wave! They are merely used for purposes of the design.

The wave arrives simultaneously at 0 and A. At 0 it is reflected, whereas it continues to run from A as far as 4 to the reflection. In the meantime, however, the part of the wave, reflected at 0, has covered a path section A 4. We therefore describe round 0 as the



centre a circle of radius of A 4. We do the same with the wave front 1 B, describing therefore round 1 a circle of radius of B 4, etc. The circles drawn in this way represent elementary waves, originating from the points of the boundary surface 0 4.

The reflected wave front is the envelope of all circles appearing as a common tangent perpendicular to all circles and passes through 4.

We assume first of all $\alpha \neq \beta$. The triangles 0 A 4 and 0 A' 4 have the same sides A 4 and 0 A' by postulate and in addition the side 0 4 is common to both. The angle at A is a right angle, as is that at A'. The two triangles are therefore congruent. In consequence $\alpha' = \beta'$ and therefore $\alpha = \beta$.

Scattered reflection at rough surfaces

August 1975 - 2014

Sonntag		3	10	17	24	31
Montag		4	11	18	25	
Dienstag		5	12	19	26	
Mittwoch		6	13	20	27	
Donnerstag		7	14	21	28	
Freitag	1	8	15	22	29	
Samstag	2	9	16	23	30	

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Mekometer III: Electronic Distance Measurement with a Resolution Less than 1 mm

Under the title "Mekometer III: EDM with Submillimetre Resolution" an article by Dr. K. D. Froome of the National Physical Laboratory, Teddington, England, appeared in the "Survey Review", 1971, No. 161. The following introduction to this article outlines in concise form the principles underlying the development of the Mekometer:

"The objective has been to design a high-resolution EDM instrument intended for short and medium-range distances. Such an instrument would, in addition to general survey work, be suitable for civil engineering applications and the measurement of large structures. It is also desirable to avoid applying corrections to the phase-measuring system; to remove the necessity for elaborate error-eliminating routines; and, if possible, to correct automatically for the effect of atmospheric refractive index without making on-site measurement of air temperature and pressure. By the time the Mekometer had completed the Mk III prototype stage of development it had achieved all these objectives. The mode of operation is completely different from all other instruments at present available. The Mekometer makes use of optical radiation for carrier wave but polarization modulation is used instead of the customary amplitude modulation. The modulation frequency is very high (around 500 MHz) so that the distance resolution is excellent. UHF modulation has the additional advantage that the phase measurement can be made by means of an optical variable light path instead of an electrical system.

The modulation wavelength is determined by reference to the resonance of a small microwave cavity resonator constructed of fused quartz and operating at nine times the modulation frequency corresponding to the basic measuring unit. This unit is one foot for the "Imperial" Mekometer or 30 cms for the "metric" Mekometer.

The Mekometer III has evolved from the Mk I which operated at 9 GHz modulation frequency[1]) and the Mk II, using 500 MHz, which was the first experimental field model to be constructed[2])."

[1]) Froome K. D. and Bradsell R. H.: Distance measurement by means of a light ray modulated at a microwave frequency.
Journal of Scientific Instruments, 1961, No. 38.

[2]) Froome K. D. and Bradsell R. H.: A new method for the measurement of distances up to 5000 ft. by means of a modulated light beam.
Journal of Scientific Instruments, 1966, No. 43.

Dr. K. D. Froome (left) and R. H. Bradsell, the spiritual parents of the Mekometer, with the Mekometer III on the lenght measurement test stand at the National Physical Laboratory, Teddington, England

September 1975 - 2014

Sonntag		7	14	21	28
Montag	1	8	15	22	29
Dienstag	2	9	16	23	30
Mittwoch	3	10	17	24	
Donnerstag	4	11	18	25	
Freitag	5	12	19	26	
Samstag	6	13	20	27	

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The Quartz Crystal as the Frequency-determining Element in the Electrical Oscillating Circuit

In 1880 *P. Curie* discovered the property of a number of crystals of building up an electric charge at both ends of the axis in the case of a mechanical deformation. This process is also reversible, i.e. the same crystals are deformed in an electric field. An electric alternating field, applied to the ends of the axes, excites these crystals to oscillate.

As a result of the lattice structure of the molecular crystal structure, these crystals have sharply differentiated characteristic oscillation frequencies. This property is particularly marked in the quartz crystal (SiO_2). It is characterized by a very constant resonance frequency.

Plates, cut in a determined direction from a quartz crystal, can therefore be used, in place of a frequency-determining oscillating circuit, for the generation of oscillations of constant frequency in oscillators. The frequency is a function of the dimension of the crystal plate.

In electronic distance meters the modulation frequency forms the standard. This standard must be retained over a long period and over a wide temperature range.

Quartz oscillators are the most common elements, used to generate the modulation frequency with the required constancy.

The oscillating crystals, contained in these oscillators, are pre-aged and only vary their frequency as a function of time with an order of magnitude of 5 to $10 \cdot 10^{-6}$/year. Tuning trimmers are provided, so as to be able to correct even these small deviations.

The frequency drift as a function of the temperature is maintained within narrow limits either by electronic compensation circuits or by heating of the quartz crystal to a temperature outside the operating range of the instrument (e.g. 75° C). Normal values are, depending on the system, $0.2\text{-}0.5 \cdot 10^{-6}$/°C.

Quartz crystals (SiO_2) from the neighbourhood of the Rhone glacier (Valais). The crystal on the right belongs to the largest and most beautiful mountain crystals, found in Switzerland; it is 65 cm long and weighs 56 kg (Natural History Museum, Berne)

Oktober 1975 - 2014

Sonntag		5	12	19	26
Montag		6	13	20	27
Dienstag		7	14	21	28
Mittwoch	1	8	15	22	29
Donnerstag	2	9	16	23	30
Freitag	3	10	17	24	31
Samstag	4	11	18	25	

Kern & Co. Ltd.
Optical and
Mechanical Precision
Instruments
CH - 5001 Aarau
Switzerland

An Ideal Instrument Combination for Cadastral Survey in Densely Built-up Areas

Old city centres with their winding alleys and narrow streets often present the survey engineer with considerable difficulties in the positioning of polygon traverses for the detailed surveys. Short sighting ranges alternate with long, while pedestrian and vehicle traffic is busy on the sector for measurement. Projecting corners and narrow passages require improvisation.

An instrumentation which can adapt itself to these conditions affords the best guarantee of a rapid and reliable measurement. The DM 500 - DKM2-A combination is under these conditions an ideal combination of instruments. The theodolite gives with a single reading in one telescope position a directional accuracy of better than ± 15^{cc}/5″. This corresponds at a distance of 200 m to a lateral deviation of not more than ± 5 mm. The indication of random errors as a measure of accuracy is not reasonable for electronic distance meters, since the majority of the errors are systematically distance-dependent. Nevertheless, maximum errors can be given, which are not exceeded. It has to be borne in mind however that, as a result of the systematic nature of the errors, more errors occur in the neighbourhood of the limiting values. These limiting values are located at about 1 - 2 cm. They can be reduced to about 50% by an accurate calibration. Apart from its high accuracy, the DM 500 - DKM2-A instrument combination has no equal in respect of weight, smallness, nature of the combination of distance meter and theodolite, automatic measurement and convenient read-off.

Interruption of the beam during measurement is unimportant. Any distance in the field of cadastral survey is measured with the same accuracy. In order to ensure minimum interference from the power supply, the battery cable is connected to the fixed lower part of the theodolite. The DM 500, which merely slides on to the body of the telescope, can thus be rotated at will together with the support round the vertical axis. The battery remains in this case attached to the tripod. It is even possible to carry the complete equipment on the tripod. Even for measurement of polygon angles in both telescope positions, it is not necessary to dismantle the DM 500, since the telescope can always be plunged. The fact that for each surveyed point only one sighting is necessary on the narrow reflector for distance, horizontal direction and vertical angle, brings out the versatility and convenience of measurement of this survey system.

The Kern DKM2-A one-second theodolite with attached Kern DM 500 electro-optical distance meter during detailed survey in the old city of Basel

November 1975 - 2014

Sonntag		2	9	16	23	30
Montag		3	10	17	24	
Dienstag		4	11	18	25	
Mittwoch		5	12	19	26	
Donnerstag		6	13	20	27	
Freitag		7	14	21	28	
Samstag	1	8	15	22	29	

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The Nature of Light

The first scientific theories on light were formulated in the seventeenth century: the emission theory of *Newton* and the wave theory of *Huygens*. According to the former, light consists of luminous particles and according to the latter of oscillations or waves. The argument between the two theories was decided initially in favour of the wave theory as the result of the interference capacity of light.

The achievement of *Kohlrausch* and *Weber* in 1856 in measuring electrically the propagation velocity of electromagnetic waves, which yielded a good agreement with the previously determined velocity of light provided the stimulus for the electromagnetic theory of light of *Maxwell*, in which light was regarded as an electromagnetic oscillation. *Heinrich Hertz* showed that wave trains, emitted from an electric oscillator undergo linear polarization and, like light waves, are reflected and refracted at boundary surfaces. The frequency of the emitted waves is a function of the oscillator dimensions. Atoms and molecules were thus found to be the generating oscillators for visible light. This gave rise to the classical concept of light emission: electrons, under the influence of external excitation, oscillate round equilibrium positions and emit light waves.

Experimental investigations with incandescent solid bodies ("black bodies") showed that the radiation intensity increases with a rise in frequency to a determined maximum, then falling rapidly at even higher frequencies. This is in contradiction to the results of the classical theory, according to which the radiation intensity should exhibit an unlimited increase with a rise in the frequency ("ultraviolet catastrophe").

Plank solved the contradiction in the year 1900 by introducing a new natural constant, the Planck quantum h. According to *Planck* energy cannot be emitted in any desired quantities, but only in multiples of h, namely light quanta or photons. The resulting quantum theory prevails today over the greater part of physics. *Niels Bohr* produced for the first time in 1913 a model of the atom on the basis of the quantum. The electrons revolve in discrete orbits round the nucleus of the atom; each steady-state orbit is characterized by a quantum number n. n = 1 corresponds to the basic orbit, the lowest energy orbit.

If an electron "jumps" as a result of external influences from a high-energy level E_1 to a low-energy level E_2, it emits the energy difference $E_1 - E_2$ in the form of light. In this case

$h.v = E_1 — E_2$ (v being the frequency of the emitted light).

The line spectra of simple atoms can be explained by this Bohr model of the atom without difficulty. The Bohr theory is not however sufficient in the case of atoms with a more complex structure. The state of an electron is no longer determined by one, but by four quantum numbers.

If X-ray radiations undergo scattering at a substance with loose electrons, the scattered radiation has a longer wavelength than the incident radiation. The lost energy reappears in "recoil electrons", which are ejected from the atom of scattering material during the scattering process. Such phenomena can only be explained by a corpuscular radiation, in which the light quanta act as projectiles.

This wave-corpuscle dualism occurs only in the atomic range. To solve the contradiction, the centuries old causality principle had to be abandoned for this range.

Even the faint light of a small lamp radiates warmth and shelter

Dezember 1975 - 2014

Sonntag		7	14	21	28
Montag	1	8	15	22	29
Dienstag	2	9	16	23	30
Mittwoch	3	10	17	24	31
Donnerstag	4	11	18	25	
Freitag	5	12	19	26	
Samstag	6	13	20	27	