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# Recent Development of Integrated Automation in Digital System for Precise Measuring Survey in Japan

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## 1. Abstract

The recent advance in Electro-Distance Measurement Instrument (EDM) in Japan using the integrated automation of digital systems was contributed to by the development of appropriate optical source.

At present this new EDM with the high precision combined to other instruments such as the digital transit, X-Y plotters and mini-computers, a total system for precise measurement has been developed and used in engineering in Japan. In this report we discuss first the newly developed EDM instrument and integrated systems which use it.

The EDMs now on the market have all adopt semi-conduct on optical source such as LED or laser diode, since this makes them easy and convenient to use. However, in these EDMs, the highest resolving power is on the order of 1 mm, and if this is to be increased, then a gas laser and an Xenon lamp together with an electro-optical modulator must also be used.

This report focuses on the use of laser diodes which have recently reached a state of high development. In the experiment discussed here a modulated signal over 1 GHz carried by a laser diode obtained a 0.01 resolving power. The results of experiment were good although distances considered were short.

## 2. Items for Technical Examination

### 2.1 Modulated Frequency

If the intention is to obtain a 0.01 mm resolving power, the first consideration must be that of the modulated frequency. At presnt, ordinary EDMSs widely use a 15 MHz–75 MHz modulated frequency to obtain a resolving power of 1 mm. If the target is to obtain 0.01 mm resolving power, 1500 MHz is a desirable modulated frequency, however in this experiment, 1200 MHz was used.

### 2.2 Optical Source and Transmitted Photo Sensor

One research paper on the use of a laser diode as an optical source, reported the successful use of modulation up to 2000 MHz in experiments.

The characteristics of the diode for this report are shown in Fig. 1.

The PIN photo diode was selected of the receiver photo sensor. The laser diode and electro circuits, therefore between these diode and focal point of objective lense are linked with a long glass fiber.

### 2.3 Oscilator Circuit and the Total System of Circuits

Exactly the same type of main oscilator was used and the original frequency became 15 MHz (precisely 14.98545 MHz). By using this 15 MHz, one of the two phase locks was multiplied 80 times and the other 81 times, and gained results were 1200 MHz and 1215 MHz respectively. The former was used as the optical modulating signal of laser diode and the latter as the local

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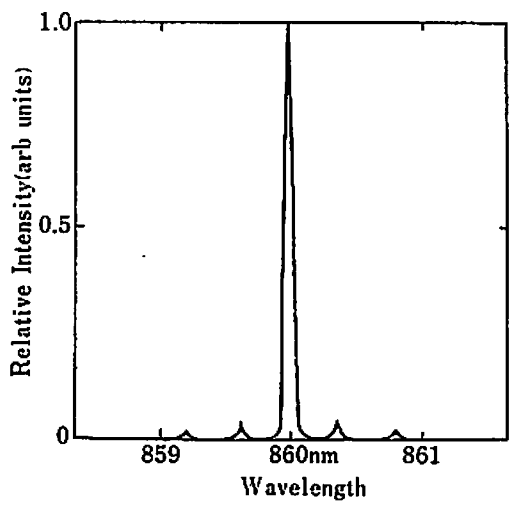
| PARAMETER | | ML-2205 |
|---|---|---|
| Light Output (Peak) | mW | 3.5 |
| Reverse Voltage | V | 3.0 |
| Operating Case Temperature | °C | −40~+50 |
| Storage Temperature | °C | −55~+100 |

| PARAMETER | | ML-2205 | | |
|---|---|---|---|---|
| | | Min. | Typ. | Max. |
| Threshold Current | mA | | 30 | 60 |
| Operating Current | mA | | 40 | |
| Light Output (Peak) | mW | | 3 | |
| Operating Voltage | V | | 1.8 | |
| Lasing Wavelength | nm | 800 | | 900 |
| Full Angle at Half Maximum | deg | | 10.40 | |
| Modulation Efficiency | nW/mA | | 0.3 | |
| Cutoff Frequency | GHz | | 2 | |
| Monitoring Light Output | mW | 0.3 | | |
| Reverse Current | μA | | | 10 |
| Differencial Resistance | Ω | | 6 | |
| Thermal Resistance | °C/W | | 150 | |

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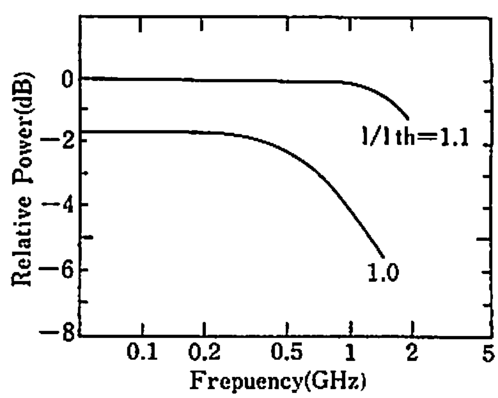



FREQUENCY RESPONSE.

Fig. 1 Characteristics of Laser Diode

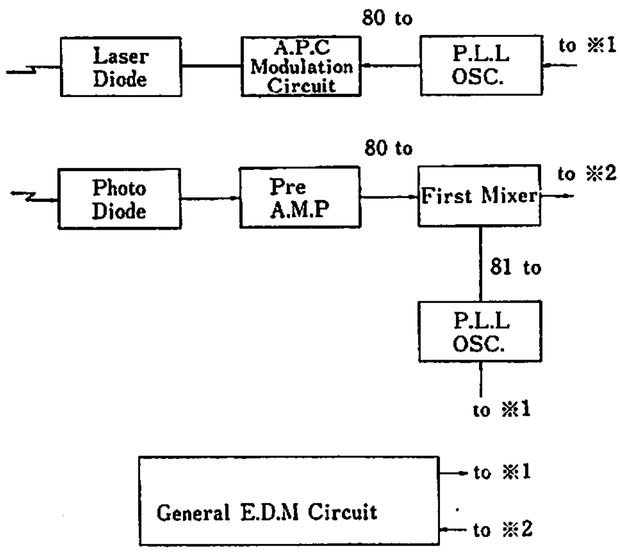



Fig. 2 Block Diagram of Overall System

signal of the mixed circuit. Then the modulated frequency after the mixture becomes 15 MHz and since the circuit system for the ordinary EDM circuit can be used as it is, the total system is very much simplified. A block diagram of the overall system is shown in Fig. 2.

## 2.4 Optical system

The optical system is no different from an ordinary EDM. One half of a objective lens is for the transmitter and the other half is for the receiver, and in optical system for pointing, the same objective lens is used. A sketch diagram of the optical system is shown in Fig. 3.

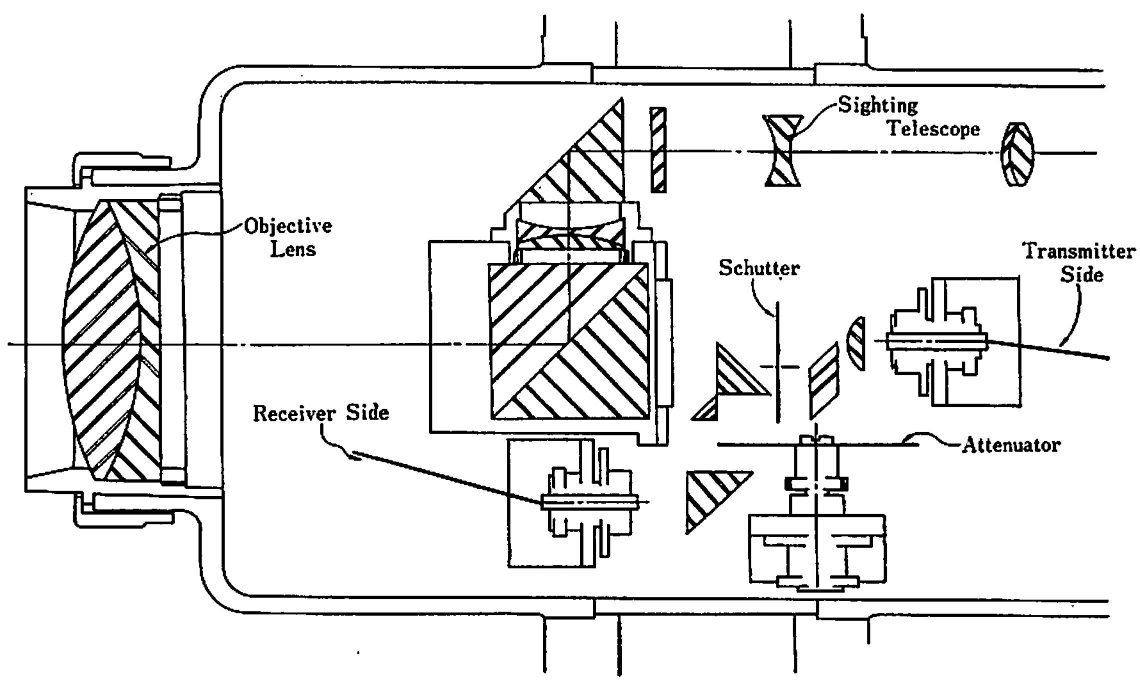



Fig. 3 Sketch Diagram of Optical System

### 2.5 Optical efficiency

The power of the laser diode is about 3 mW, however because of losses caused by linkage with fiber and transmitters, about 1 mW is considered have thus been lost. The receiving power is varied with distance, however since a photo diode is used and it's load is 50 Ω, therfore the noise level is calculated into optical power as $(0.4/10^{-5})\mathrm{mW/Hz^{1/2}}$. This power is equivalent to an optical power of approximately 600 m distance. However, for practical use, it is probably about 60 m which is about the 1/10 of the result.

The sketch diagram of the power level of the incident light is shown in Fig. 4.

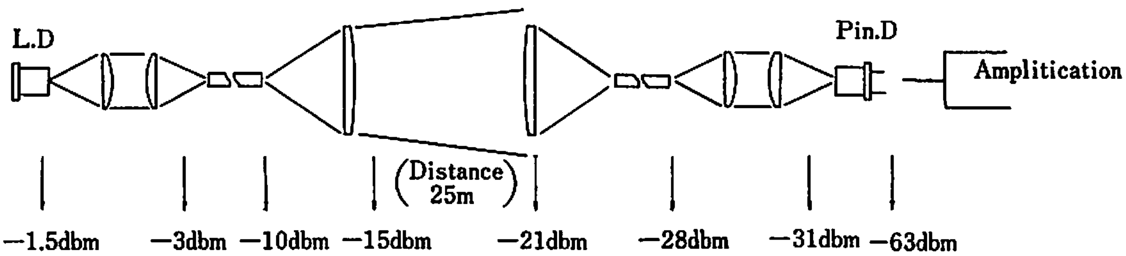



Fig. 4 Sketch Diagram of Power Level of Incident Light

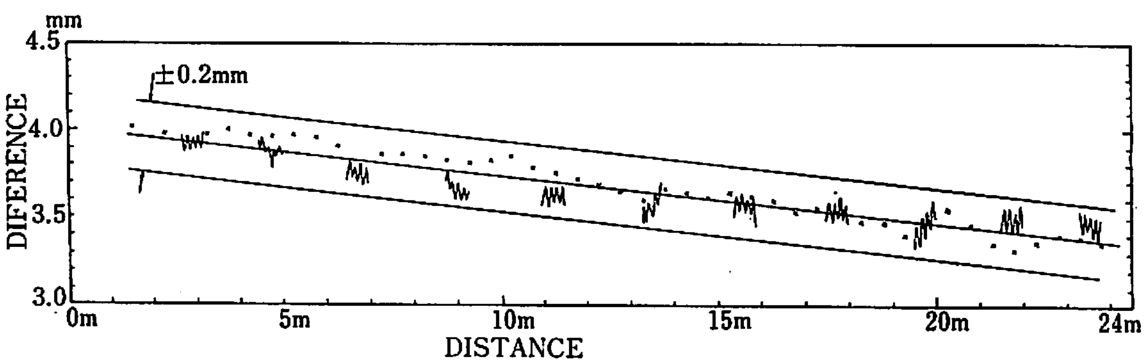
## 3. Results of Experiments

### 3.1 Resolving power

The experiment for simultaneous comparison with the laser interferometer of H.P. confirms that 0.01 mm is easily obtained.

### 3.2 Precision

As is the case of 3.1, simultaneous comparison with laser interferometer of H.P. is tested experimentally and results are confirmed to fall in the range of ±0.1 mm. (see Fig. 5)




Distance versus [real-measured] distance, which represents the results of preliminary test of the optical measuring instrument. The instrumental constant is shown as a thick line.

Fig. 5 Result of Distance Measurement

In this experiment, two laser interferometeers are used. On precisely laid rails of 100 m length and 0.5 mm width, two interferometers are placed at either end and between them, the instrument described above is placed. The room in which this experiment took place is narrow, tunnel-like, with a controlled temperature of +20°C±1°.

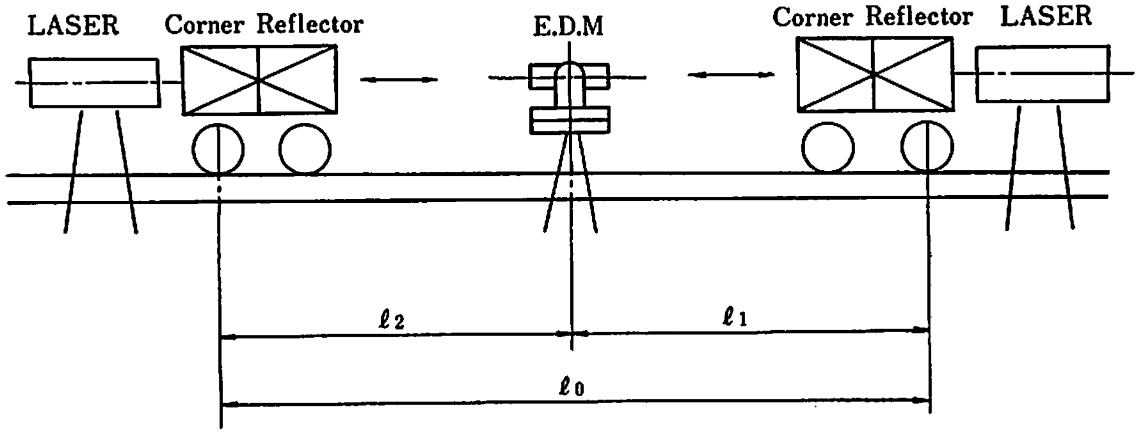



Fig. 6 Determination of Mechanical Constant

$l_0$ is measured by laser interferometer before two EDMs are placed.

$l_0 = l_1 + l_2 + 2k_1$ $\qquad k$: mechanical constant

### 3.3 Measured distance

In this experiment, the measured distance is about 25 m. This is probably due to the losses in the optical system. If the diameter of the objective lens were made larger, 100 m or more could probably be measured. The distances in hte 500 m–1000 m range, can not be measured by one color laser due to the problem of atmospheric correction.

## 4. Future Problems

In this experiment, the results are technically almost as good as we expected, however several problems must be solved for future commercial production.

### 4.1 Determination of mechanical constant

The mechanical constant must be determined by actual measurement. Two interferometers operating on a specially designed rail system at constant temperatures would be necessary.

### 4.2 Corner reflector

The constant of corner reflector is difficult to determine. Perhaps the easiest way would be to measure it on the spot as in the case of 4.1. At that time, the positions of the corner reflector and it housing would also have to be precisely measured.

### 4.3 The obervational errors in the placement of the instrument and the corner reflector

In this experiment, the absolute length is measured by two laser interferometers and by comparison with these results, precision is established. However, in the field, such a procedure could not be used.

### 4.4 Alignment errer between corner reflector and optical axis

As the incident surface and the optical axis for distance measuremnt of the corner reflector do form a perfect right angle, due to the discrepancy between the reflection index and the optical path, measured distances are slightly affected. The difference can be calculated at 0.2 mm for a angle of 10 degree and for 20 degree, it is1.1 mm.

## 5. Integrated Automation System for Making Highly Precise Measuring Survey

As mentioned in this paper, we have developed a new EDM with high level of precision. By combining this and such other instruments such as the digital transit, X & Y recorders and the mini-computer, a total system for precise measuremnt has been developed and used for various purposes in Japan. At present many mini-computers are used in engineering to spot check data measured in the field, and to systematically control rojects using integrated automation systems either on-line or off-line. In this paper, since space is limited, these various kinds of integrated systems and their use in making precise measurements in Japan, can not be considered.

## 6. Conclusion

A total system using electro-distance measurements to make a precise survey under laboratory conditions can thus be produced. For this method to be used commercially the problem of error control would have to be overcome. In this experiment, the target for measurement is under 100 m. Thus this method can be applied to such large scale uses as architecture, ship building, LNG tank, etc. If the method is applied to projects using a much larger scale such as the movement of the earth's crust, the target distances become much longer and due to atmospheric corrections the high resolving power which is the characteristic at this method cannot be used unless the adoptation of multicolour is made possible.