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Measurement methods of lenses for fiber optic transmission

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Foreword

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Measurement methods of lenses for fiber optic transmission

Introduction This Japanese Industrial Standard has been prepared for specifying the common test methods of lenses for fiber optic transmission corresponding to **JIS C 5934** *General rules of lenses for fiber optic transmission*.

1 Scope This Standard specifies the test methods of the microlenses used mainly for optic transmission.

2 Normative references The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standard (including amendments) indicated below shall be applied.

JIS B 7094 *Photographic lenses—Measurement for the focal length*

NOTE : **ISO 517** : 1996 *Photography—Apertures and related properties pertaining to photographic lenses—Designations and measurements* is equivalent to the said standard.

JIS C 5860 *General rules of passive devices for light beam transmission*

JIS C 5901 *Test methods of passive devices for fibre optic transmission*

JIS C 5934 *General rules of lenses for fiber optic transmission*

JIS C 60068-1 *Environmental testing Part 1 : General and guidance*

NOTE : **IEC 60068-1** : 1988 *Environmental testing Part 1 : General and guidance* is identical with the said standard.

JIS Z 8120 *Glossary of optical terms*

3 Definitions For the purpose of this Standard, the definitions given in **JIS C 5860**, **JIS C 5901**, **JIS C 5934** and **JIS Z 8120** and the following definitions apply.

- a) **standard light source** light source of essentially small wavefront aberration, necessary and sufficient coherence, and necessary and sufficient stability in output power in a range of the working wavelength
Usually gas laser such as He-Ne gas laser, solid state laser and semiconductor laser (hereafter referred to as “LD”) are used. In addition, light emitting diode (hereafter referred to as “LED”) and the like can be used together with appropriate optical correction system.
- b) **standard lens** lens of necessarily and sufficiently small transmission wavefront aberration in working wavelength and in a given magnification within an effective diameter and of the known transmission loss including internal reflection loss
Usually, the effective diameter and effective focal length or effective NA are clearly indicated and anti-reflection coating is given. An example is the objective of optic microscope.

- c) **beam reduction optical system** a lens system in which lens 1 and lens 2 of f_1 and f_2 ($f_1 \geq f_2$) in respective focal length are set in confocal arrangement. Parallel light beam is converted to the parallel light beam the diameter of which is reduced by this system. The rates of reduction are given by f_2/f_1 . Reverse optical system of beam expander.
- d) **optical fiber for measurement** optical fiber of ignorable combined loss with the standard lens and having large NA and core diameter enough to receive all luminous flux converging from the standard lens. The end surface is vertical or inclined according to the uses. Reflectionless coating is given where appropriate.
- e) **collimator** an instrument to make the light which has passed through the slit, pinhole, etc. placed on the position of the focal point of lens or reflecting mirror a parallel light flux.
- f) **image of limiting aperture** image of a given limiting aperture inserted in an optical system which has been formed by a lens on the pupil face of the microlens being tested, pupil face of the standard lens or light receiving element of optical power meter.
In the microlens being tested, the effective diameter, namely, the domain where the wavefront aberration is known is specified.

4 Test conditions

4.1 Standard atmospheric conditions Unless specified otherwise, the test and measurement are carried out under the standard condition [temperature 15°C to 35°C, relative humidity 25 % to 85 % and air pressure 86 kPa to 106 kPa (860 mbar to 1 060 mbar)] specified in **5.3 of JIS C 60068-1**. If the assessment based on the measured value under this condition or if required in particular, **4.3** applies. In addition, if conversion is required, the following **4.2** applies.

4.2 Standard reference atmosphere The standard reference atmosphere [temperature 20°C, air pressure 101.3 kPa (1 013 mbar)] specified in **5.1 of JIS C 60068-1**. The standard reference conditions may be defined based only on the temperature.

4.3 Referee conditions The standard atmospheres for referee measurements and tests (referee conditions) I temperature class 2 and humidity class 2 [temperature 20°C $\pm$ 2°C, relative humidity 60 % to 70 % and air pressure 86 kPa to 106 kPa (860 mbar to 1 060 mbar)] specified in **5.2 of JIS C 60068-1**.

4.4 Condition of test site The test site is made fully clean so as to be free from waste, dust, etc. Moreover, precautions are observed so as to avoid external obstruction such as wind and vibration.

5 Appearance and construction Clause **5** of **JIS C 5901** applies.

6 Optical performance test

6.1 Common equipment

- a) **Light source** Unless specified otherwise, standard light source is used. Usually, the light source of the wavefront aberration of $\lambda/10$ or under in working wavelength and of the output stability of ± 0.05 dB/h is used. The details are given in individual specification.

- b) **Lens** Unless otherwise specified, standard lens is used. Usually, the lens of wavefront aberration of $\lambda/10$ or under in working wavelength is used. The details are given in the individual specification.
- c) **Limiting aperture** Unless otherwise specified, circular diaphragm is used.
- d) **Collimator** Unless otherwise specified, collimator of the beam diameter larger than the maximum diameter of the limiting aperture and of the wavefront aberration not more than $\lambda/10$ in working wavelength is used. The details are given in individual specification.
- e) **Optical fiber** Unless otherwise specified, the optical fiber being tested and the optical fiber for measurement of sufficient length enough to strip the cladding mode so as not to affect the measurement accuracy and of the light loss of optical fibers themselves is sufficiently small compared with the combined loss of the microlens being tested are used. In particular, in the case of single mode optical fiber, the cladding mode is stripped in, for example, such a way that a mode filter of 2 m length having two loops of the diameter of approximately 50 mm is placed in its light path. The details are given in individual specification.
- f) **Beam reduction optical system** The beam reduction optical system such that a limiting aperture of known diameter is combined in advance in the back side principal point or in its vicinity is used. Its wavefront aberration shall be $\lambda/10$ or under in working wavelength. The details are given in individual specification.
- g) **Optical power meter** Unless otherwise specified, the optical power meter of the linear error including loss depending on polarization in the measurement range is within 0.05 dB, of the required sensitivity and capable of fully obtaining the dynamic range is used. The light receiving element used shall be of uniform sensitivity distribution and of the effective light receiving diameter large enough for the core diameter of the optical fiber for measuring incident light power, the core diameter of the optical fiber being tested and the effective diameter of the microlens being tested. The power at the light receiving surface is preferable to be lower at least 10 dB than saturation level of the light receiving element.
- h) **Image taking element** The image taking element of uniform sensitivity distribution for the wavelength being measured and capable of sufficiently obtaining dynamic range is used. Moreover, the one of plane type having sufficient space resolving power enough to carry out a given analysis is used.
- i) **Semi-transparent mirror** Unless otherwise specified, the semi-transparent mirror of the absorptance not more than 0.5 % and of the effective area larger than the largest diameter of the limiting aperture is used. On the face opposing the face having partial reflection coating, nonreflective coating shall be used. In addition, the wavefront aberration shall be $\lambda/10$ or under in working wavelength.
- j) **Mirror** Unless otherwise specified, the mirror of the reflectance at least of 98 % (in both polarization compositions), of the wavefront aberration not more than $\lambda/10$ and of the sufficiently larger effective area than luminous flux diameter is used.

6.2 Preparation In order to avoid giving rise to uncertainty, the microlens being tested is allowed to stand as it is in the measurement environment at least for 1 h, if required. In addition, excessive ventilation and direct thermal radiation from sunshine and other thermal source shall be prevented so as not to enter in the test specimen as a factor likely to affect the measurement during a period before or after the measurement.

The part through which entering and outgoing light pass shall be kept clean sufficiently without dust, etc.

6.3 Microlens tolerance parameter

6.3.1 Combined effect

6.3.1.1 Equipment As given in the following :

- a) **Light source** The light source conforming to the requirements in **6.1** is used.
- b) **Collimator** The collimator conforming to the requirements in **6.1** is used.
- c) **Beam reduction optical system** The beam reduction optical system conforming to the requirements in **6.1** is used.
- d) **Limiting aperture** The limiting aperture conforming to the requirements in **6.1** is used.
- e) **Lens** The lens conforming to the requirements in **6.1** is used.
- f) **Optical fiber** The optical fiber conforming to the requirements in **6.1** is used.
- g) **Optical power meter** The optical power meter conforming to the requirements in **6.1** is used.

6.3.1.2 Test The combined effect which is obtained as a ratio of the light power received in the fiber being tested to the light power having passed through the effective diameter of the microlens being tested is measured by the following procedures 1 to 4.

NOTE : The procedures 1 and 2 are called “parallel conversion system” used when the microlens being tested is used at infinite conjugate ratio and the procedures 3 and 4 are called “combination system” in which the microlens being tested is used at finite conjugate ratio.

a) **Procedure 1 (method for specifying the effective diameter with the limiting aperture in parallel conversion system)**

- 1) As shown in figure 1, arrange respectively one end of the optical fiber of the length specified in **6.1 e)** on the position of the effective focal point of the lens 1 and the limiting aperture of the size specifying the area in which the wavefront aberration is known on the pupil surface of the lens 1 so that the collimated light is supplied to the microlens being tested. For the lens 1, a lens of the equivalent effective focal length to that of the microlens being tested and of the effective NA more than that of the lens 1 should be used. Arrange respectively the limiting aperture 2 on the pupil surface of the microlens being tested and one end of the optical fiber of the length specified in **6.1 e)** on the position of the effective focal point of the microlens being tested. Specify the effective diameter of the microlens being tested by the size of the limiting aperture 2. Measure P_1 adjusting the position of the microlens being tested so that the value of the output power of the optical power meter comes to the maximum. If there is end face reflection loss or transmission loss in the optical fiber being tested, the value resulted from the correction of relevant losses is used for P_1 . If the limiting apertures 2 cannot be arranged on the pupil surface of the microlens being tested, the limiting aperture 2 may be arranged on the position in the neighbourhood of the pupil surface where the arrangement is possible. When the aperture of the microlens being tested is taken as the effective diameter, the limiting aperture 2 may be omitted.

- 2) Then, according to the construction of figure 2, measure the quantity of the light entering into the microlens being tested. In the construction of figure 1, arrange a standard lens instead of the microlens being tested and an optical fiber for measurement instead of the optical fiber being tested respectively to form the construction of figure 2. For the optical fiber for measurement, use such optical fiber that the combined loss with standard lens can be ignored. Adjust the position of the standard lens and optical fiber for measurement so that the value of the output of the optical power meter comes to the maximum and measure the value P_0 of the output power of the optical power meter at that time. If the optical fiber for measurement has end face reflection loss or propagation loss or the standard lens has transmission loss, use for P_0 the value for which the relevant losses are corrected. In case where the light receiving face of the light receiving element of the optical power meter is sufficiently large compared with the effective diameter of the microlens being tested, P_0 at the time when the optical power meter is set at the position of limiting aperture may be measured without using standard lens and optical fiber for measurement.

- 3) Calculate the combined efficiency η by

$$\eta = 10 \log_{10} (P_1/P_0) \text{ [dB]}$$

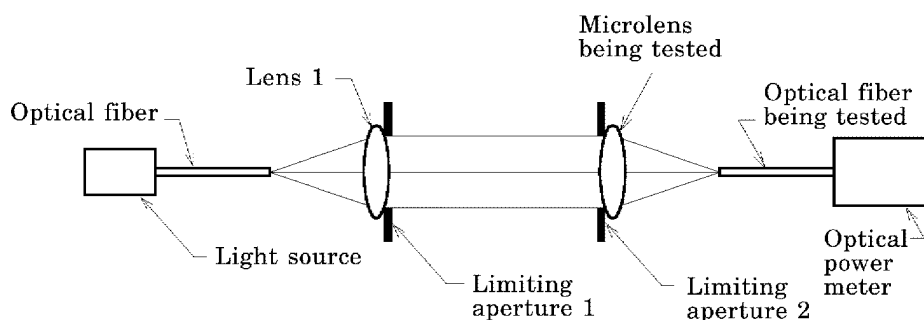


Figure 1

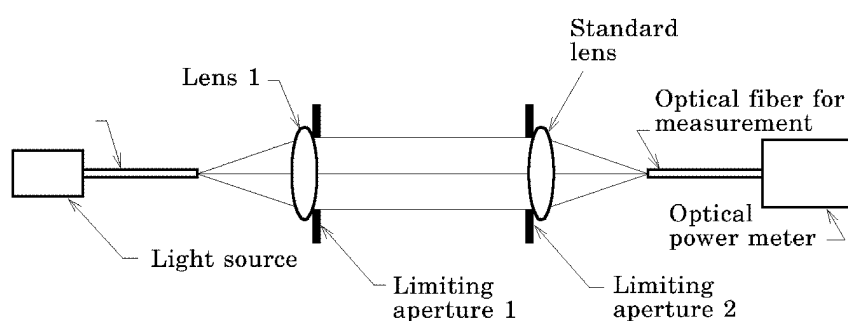


Figure 2

b) Procedure 2 (method for specifying the effective diameter with the image of the limiting aperture in parallel conversion system)

- 1) As shown in figure 3, arrange a beam reduction optical system having the limiting aperture at the back face of lens 1 on the collimated luminous flux and arrange respectively the microlens being tested in such a way that the pupil face of the microlens being tested coincides with the conjugate point by

the lens 2 of the limiting aperture and one end of the optical fiber being tested of the length specified in 6.1 e) on the position of effective focal point of the microlens being tested. Specify the effective diameter of the microlens being tested with the size of the image of the limiting aperture. Adjust the position of the microlens being tested so that the value of the output power of the optical power meter comes to the maximum and measure P_1 . If the optical fiber being tested has end face reflection loss or propagation loss, the value for which the relevant losses of which are corrected is used for P_1 .

- 2) Measure the quantity of the light entering into the microlens being tested according to the construction of figure 4. In the construction of figure 3, arrange respectively a standard lens instead of the microlens being tested and an optical fiber for measurement instead of the optical fiber being tested and form the construction of figure 4. For the optical fiber for measurement, use an optical fiber of ignorable combined loss with the standard lens. Adjust the position of the standard lens and optical fiber for measurement so that the value of the output power of the optical power meter comes to the maximum, and measure the value P_0 of the output power of the optical power meter at that time. If the optical fiber for measurement has end face reflection loss or propagation loss, or the standard lens has transmission loss, the value of corrected relevant losses is used for P_0 . If the light receiving face of the light receiving element of the optical power meter is sufficiently large compared with the effective diameter of the microlens being tested, P_0 may be measured setting the optical power meter on the position of the image of the limiting aperture without using standard lens and optical fiber for measurement.

- 3) The combined efficiency η is calculated by

$$\eta = 10 \log_{10} (P_1/P_0) \text{ [dB]}$$

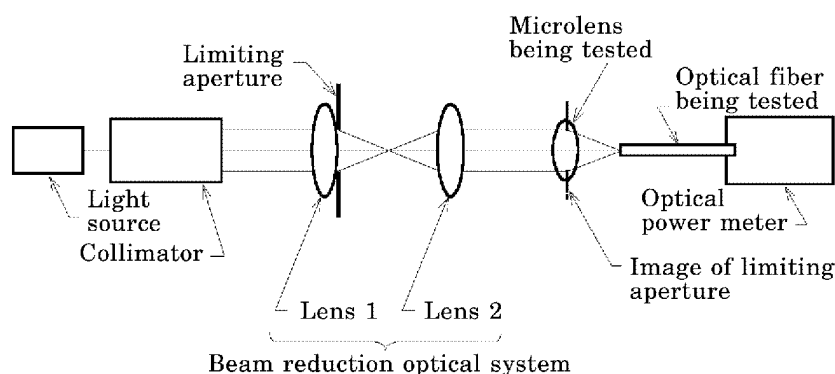


Figure 3

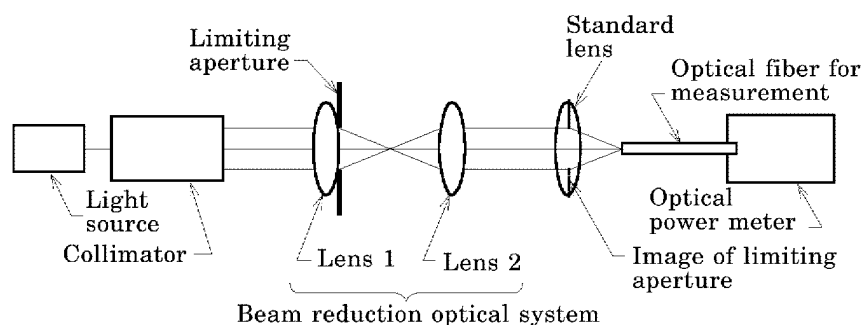


Figure 4