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REDLINE VERSION

# INTERNATIONAL STANDARD

colour inside

## Optical fibres –
## Part 1-34: Measurement methods and test procedures – Fibre curl



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International Standard IEC 60793-1-34 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

This third edition cancels and replaces the second edition published in 2006. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) modification of several derivation equations for laser scattering;
b) change of angular increment from 10° to 30° to 10° to 45°;
c) change of Annex B from informative to normative.

The text of this International Standard is based on the following documents:

| CDV | Report on voting |
|---|---|
| 86A/1971/CDV | 86A/1994/RVC |

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.



A list of all parts in the IEC 60793 series, published under the general title *Optical fibres*, can be found on the IEC website.



The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be



- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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# OPTICAL FIBRES –

# Part 1-34: Measurement methods and test procedures – Fibre curl

## 1 Scope

This part of IEC 60793 establishes uniform requirements for the mechanical characteristic: fibre curl or latent curvature in uncoated optical fibres, i.e. a specified length of the fibre has been stripped from coating. Fibre curl has been identified as an important parameter for minimizing the splice loss of optical fibres when using passive alignment fusion splicers or active alignment mass fusion splicers.

Two methods are recognized for the measurement of fibre curl, in uncoated optical fibres:

- method A: side view microscopy;
- method B: laser beam scattering.

Both methods measure the radius of curvature of an uncoated fibre by determining the amount of deflection that occurs as an unsupported fibre end is rotated about the fibre's axis. Method A uses visual or digital video methods to determine the deflection of the fibre while method B uses a line sensor to measure the maximum deflection of one laser beam relative to a reference laser beam.



By measuring the deflection behaviour of the fibre as it is rotated about its axis and understanding the geometry of the measuring device, the fibre's radius of curvature can be calculated from simple circular models, the derivation of which are given in Annex C.

Both methods are applicable to type~~s A1, A2, A3 and~~ B optical fibres as described in IEC 60793 (all parts).



Method A is the reference test method, used to resolve disputes.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60793 (all parts), *Optical fibres*

## 3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

# 4 Apparatus

## 4.1 Principle

An uncoated fibre end is mounted in a rotatable fixture so that the end extends freely into space by an overhang distance which will depend on the measurement device. The overhang distance is from the fibre fixture to the free endface of the uncoated fibre. The measurement distance from the fibre fixture to the measurement point is typically 10 mm to 20 mm, and the measurement point shall be close to the fibre's free endface. If the measurement device is designed with ~~overhang~~ measurement distances greater than this, care ~~must~~ shall be taken to avoid excessive degradation due to effects of vibration and gravity. The fibre is rotated and the deviations in the position of the ~~overhang~~ test point relative to a reference position are measured to obtain the fibre's radius of curvature, $r_c$.

Details pertaining to the two methods are given in the relevant Annex A or Annex B. Common apparatus requirements are given in 4.2 to 4.5.

## 4.2 Fibre holding fixture

Provide a fixture that holds the fibre on a constant axis at the holding position and allows the fibre to be rotated through 360°. The fixture may be a v-groove holder such as a vacuum chuck or a fibre ferrule. If a ferrule is used, take care to ensure that the inside diameter is sized closely enough to the fibre diameter to minimize variability in the deflection measurements.



## 4.3 Fibre rotator

Provide a device to grip and rotate the fibre through 360°. The device may be manually operated, or it may be driven by a rotational device such as a stepper motor.

## 4.4 Deflection measurement device

Provide a deflection measurement device according to either Annex A or Annex B.



## 4.5 Computer (optional)

A computer may be used to provide motion control, data collection and computation.

# 5 Sample preparation

Use an uncabled fibre of appropriate length for the instrument design. Remove enough coating from one end to allow mounting in the fibre fixture with the necessary overhang. The fibre should not extend much past the measuring device's required ~~overhang~~ measurement distance since excessive lengths can cause degradation as discussed in 4.1.

# 6 Procedure

## 6.1 General

Details for each method are given in Annex A and Annex B. Common procedures are described in 6.1 and 6.2.

## 6.2 Mounting of the fibre

Mount the fibre in the holding fixture so that the stripped end extends into free space with sufficient length to extend up to or beyond the ~~overhang~~ measurement distance. Typical ~~overhang~~ measurement distances range between 10 mm and 20 mm. Attach the other end of the fibre to the fibre rotator. If the ~~overhang~~ measurement distance is excessive, or the stripped fibre is substantially longer than the required ~~overhang~~ measurement distance, then the measurement may be degraded.

### 6.3 Rotation

Follow the procedure of Annex A or Annex B.

## 7 Calculation

Complete the detailed calculation of the fibre curl, $r_c$, using Annex A or Annex B.

NOTE Though the intermediate parameters used in the calculations are typically scaled in micrometres, the radius of curvature, $r_c$, is typically re-scaled in units of metres.

## 8 Result

8.1 The following information should be reported for each test:

- date of the test;
- fibre identification;
- fibre radius of curvature.

8.2 The following information should be available for each test:

- method used to determine curl;
- technique used for calculations;
- description of the equipment;
- calibration data.

## 9 Specification information

The detail specification shall specify the following:

- information to be reported;
- any deviations to the procedure that apply;
- failure or acceptance criteria.

# Annex A
(normative)

# Fibre curl by side view microscopy

## A.1 Principle

This procedure measures the radius of curvature of an uncoated fibre by determining the amount of deflection that occurs as an unsupported fibre end is rotated about the fibre's axis. By knowing the amplitude of the deflection of the fibre and the ~~overhang~~ measurement distance from the fibre fixture to the measurement point, the fibre's radius of curvature can be calculated from a simple circular model, the derivation of which is given in Clause C.1. Schematic diagrams of typical test set-ups for these techniques are shown in Figure A.1, Figure A.2 and Figure A.3.

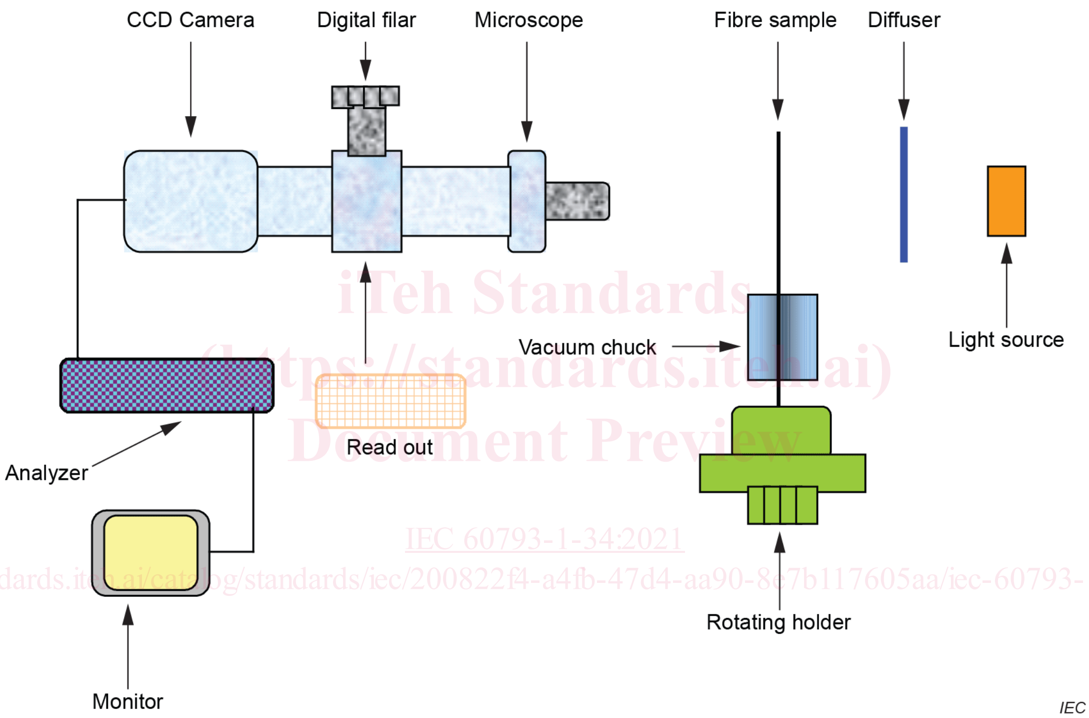




**Figure A.1 – Schematic diagram for apparatus to measure fibre curl using an optical microscope**

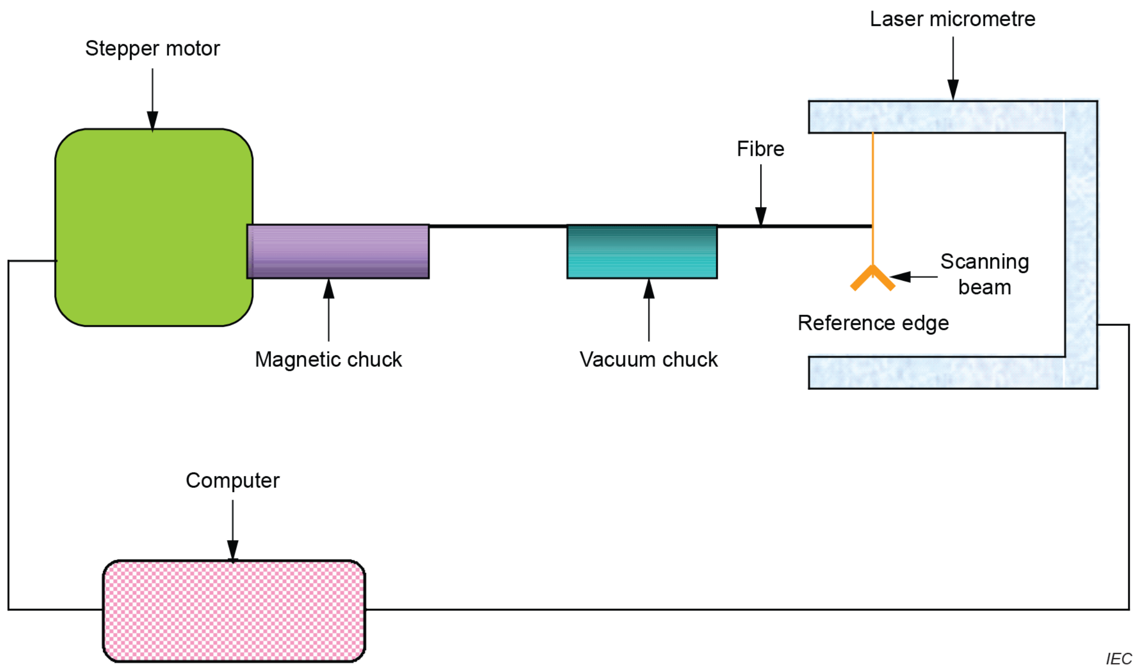


**Figure A.2 – Schematic diagram for apparatus to measure fibre curl using a laser micrometre**



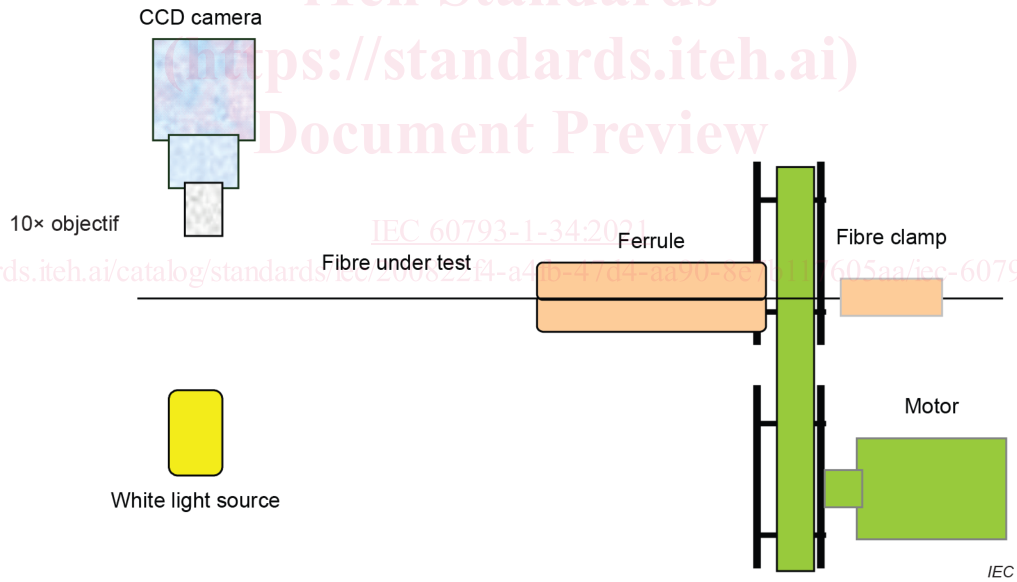


**Figure A.3 – Schematic diagram for apparatus to measure fibre curl while securing the sample in a ferrule**

## A.2 Apparatus

### A.2.1 Deflection measurement device

Provide a device to measure the fibre deflection as it is rotated through 360°. Such a device may consist of a viewing microscope or an optical measuring instrument such as a laser micrometre. If a viewing microscope is used, provide means to permit accurate measurement of fibre deflection, such as a filar eyepiece or a digital image analysis system.

### A.2.2 Video camera and monitor

A video camera and monitor may be used to enhance the viewing system for manual or automated operation.

### A.2.3 Digital image analysis system (optional)

A digital video analyser may be used to provide more precise location of the deflections than might be obtained by a filar eyepiece. Such a system might include an analogue or digital video camera, a frame grabber and associated software for the purpose of locating the fibre's position at the ~~overhang~~ measurement distance as the fibre is rotated.

## A.3 Test procedure

### A.3.1 General

Two techniques are provided for obtaining the deflection, $\delta_f$. The first is an extrema technique that is limited by the precision with which the extremes of the deflection can be determined. The second is a Fourier fitting method.

### A.3.2 Procedure for the extrema technique

Rotate the specimen until the deflection is at a maximum and record the deflection value, $D_{max}$. Rotate the specimen until the deflection is at a minimum, typically 180° from the angular position of the maximum, and record the deflection value, $D_{min}$.



### A.3.3 Procedure for the Fourier fitting technique

Record the deflection of the specimen at its initial position, $D_1$, and angular position, $\theta_1$. Rotate the specimen through 360° (do not duplicate the initial position in the data as the last angular position), stopping at equal angular increments and recording the deflection values at each increment, $D_{2...n}$, and its angular positions, $\theta_{2...n}$. Angular increments of 10° to ~~30~~ 45° are typically used.



## A.4 Calculations

### A.4.1 Extrema technique calculation

The fibre deflection $\delta_f$ is calculated by Formula (A.1):

$$\delta_f = \frac{D_{max} - D_{min}}{2} \quad \text{(A.1)}$$

where

$D_{max}$ and $D_{min}$ are the maximum and minimum deflection values, generally described in micrometres.

### A.4.2 Fourier fitting technique calculation

Compute the first order Fourier coefficients:

$$I_1 = \frac{2}{n}\sum_{i=1}^{n} D_i \times sin\theta_i \quad \text{(A.2)}$$

$$R_1 = \frac{2}{n}\sum_{i=1}^{n} D_i \times cos\theta_i \tag{A.3}$$

Compute $\delta_f$ as the magnitude of the first-order Fourier component:

$$\delta_f = \sqrt{R_1^2 + I_1^2} \tag{A.4}$$

Least squares fitting of the set of $\theta_i$ and $D_i$ may be used as an alternative. The Fourier technique described in A.4.2 and least squares fitting of the amplitude and phase are numerically equivalent.

### A.4.3 Computation of fibre curl

Fibre curl, $r_c$, is computed as:

$$r_c = \frac{Z_m^2 + \delta_f^2}{2\delta_f} \tag{A.5}$$

where

$Z_m$ is the ~~overhang~~ measurement distance.