# NEW APPROACH TO SPLICE-LOSS MONITORING USING LONG-RANGE OTDR

*Indexing terms: Measurement, Optical fibres*

Absolute splice-loss measurements on single-mode optical fibre are performed from one cable end only using specially developed long-range OTDR equipment in conjunction with a reflector at the far end of the fibre. Active splice-alignment with single-mode OTDR is also demonstrated.

*Introduction:* It is well known that splice-loss measurements by OTDR are influenced by differing backscatter factors for the fibres on either side of the splice. This effect can be compensated to give the true splice loss by taking a second OTDR measurement from the far end of the fibre and averaging the two splice-loss measurements. However, this technique is cumbersome in the field, since the remote cable end may be many kilometres away. The present contribution describes a new and simple approach to OTDR splice measurements which is made feasible by recent advances in long-range single-mode OTDR equipment.[1,2] The technique enables the measurement to be performed from only one cable end.

*Approach:* A reflector is applied to the cleaved far end of the fibre, as illustrated in Fig. 1. In our case a front-silvered mirror was butted against the fibre end, a method which readily gives reflectivities as high as 90%. In practice the reflector could be applied to the fibre prior to installation, e.g. by dip-coating. In the time interval up to twice the transit period of the probe-pulse in the fibre (i.e. $0 < t < 2l/v_g$ for a fibre of length $l$ and group velocity $v_g$), the OTDR measurement yields the normal backscatter signal at the launch end (Fig. 1*a*). However, in our case the probe pulse is reflected at the far end of the fibre. Thus, in the period $2l/v_g < t < 4l/v_g$, backscatter is received from the probe pulse returning to the launch end, the scattered light having been reflected at the mirror before reaching the launch end (Fig. 1*b*). Forward scatter from the outward and return journeys of the probe pulse will also reach the launch end of the fibre, but will arrive simultaneously with the reflected probe pulse at time $t = 2l/v_g$.

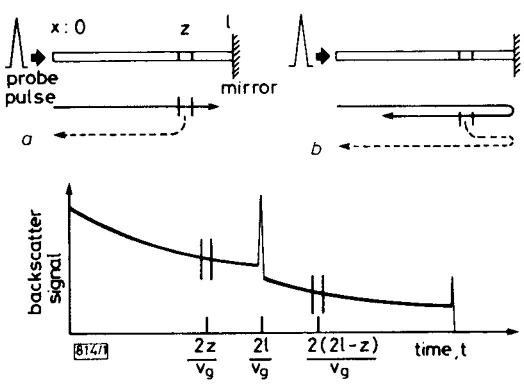


**Fig. 1** *Folded-path OTDR technique*
*a* $0 < t < 2l/v_g$
*b* $2l/v_g < t < 4l/v_g$

*Measurement system:* The proposed folded-path OTDR technique requires backscatter apparatus which has a measurement range comfortably in excess of the entire fibre length, and which incorporates optical gating to reduce the reflected probe-pulse signal. Additionally, for accurate single-mode splice measurements the detection of the backscatter signal must be insensitive to polarisation. A diagram of the single-mode OTDR apparatus used to evaluate the technique is shown in Fig. 2. The performance of the system is reported elsewhere,[2] but it is worth noting here that the design is potentially field-portable. The source is a 1·3 μm laser diode, the detector a PIN photodiode, and the system has a 30 dB one-way dynamic range for nonreflecting fault location with 100 m resolution. The range for 0·1 dB accuracy is 22 dB in a 20 min measurement time. Optical gating is accomplished by an acousto-optic deflector driven by a programmable pulse generator to allow the desired parts of the backscatter trace to be selected and reflections eliminated.

*Results:* Fig. 3 shows a backscatter trace obtained without averaging on a short demonstration fibre using the folded-path OTDR technique. The 7 km single-mode fibre has splices at 1 and 5 km. The splice losses measured from the backscatter trace are indicated in Table 1. The values were

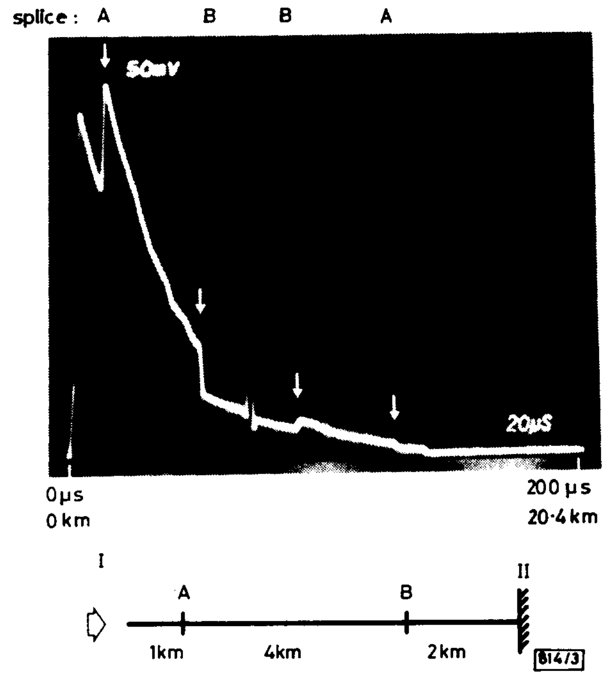


**Fig. 3** *Splice-loss measurement using folded-path technique*

**Table 1** SPLICE-LOSS VALUES

| Splice | End I | End II | Mean |
|---|---|---|---|
| | dB | dB | dB |
| A | −0·85 | 1·14 | 0·15 |
| B | 1·11 | −0·70 | 0·20 |

obtained from a digitised and averaged trace by fitting exponential curves to sections of the trace from 200 to 500 m each side of the splice. The splice loss is then given by the difference between the two fitted curves at the splice position. This technique compensates for the small fibre loss within the 100 m spacing of the sample points, and averages any localised backscatter factor variations[3] in the regions of fibre adjacent to the splice. The results shown in Table 1 illustrate how the normal single-ended measurement is strongly affected by backscatter factor differences between the joined fibres. However, the average value, obtained from a single backscatter trace with the folded-path OTDR technique, gives the true loss.

*Splice alignment:* Active alignment of single-mode fibre splices is desirable to achieve the lowest losses,[4] particularly when the fibre cores are slightly eccentric. OTDR is ideally suited to providing the alignment information if the backscatter data can be transmitted to the jointing bay. The dynamic range of the OTDR must be sufficient to allow the splice-loss data to be updated rapidly. With our apparatus, the range for 0·1 dB accuracy in a one second measurement time is 15 dB one way. Thus an OTDR set located at the terminal fibre end is able to measure the loss of an unmade splice almost instantaneously and then relay the data to the jointing bay on another communications channel. In this way active splice alignment can be achieved at a range of up to 15 dB from the terminal end, or 30 km or so with modern fibre. After splicing the absolute joint loss can be measured using folded-path OTDR and similarly transmitted.

The principle is demonstrated in Fig. 4 where the loss at a butt joint measured by OTDR is shown as a function of fibre

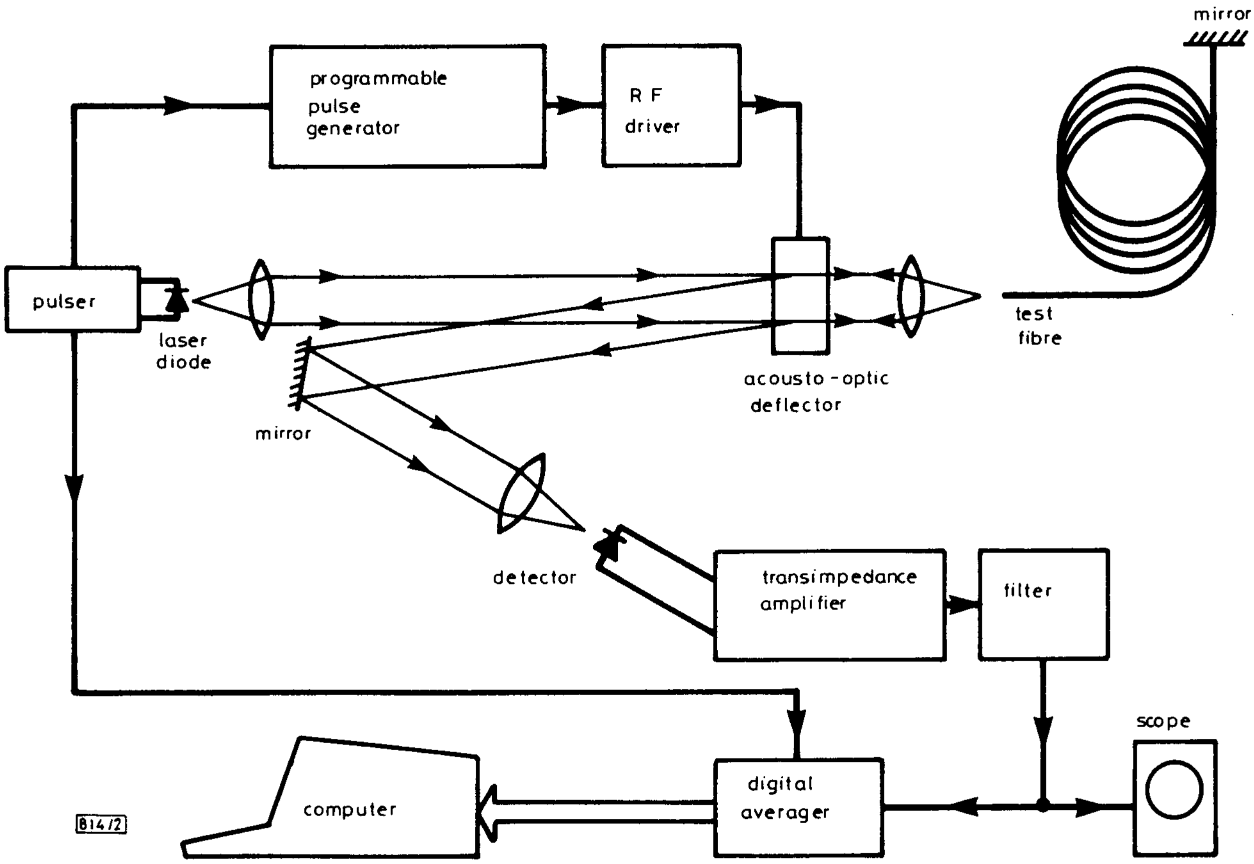


Fig. 2 *Folded-path OTDR measurement system*

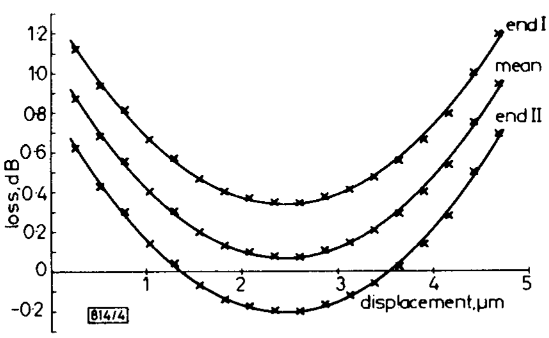


Fig. 4 *Joint-loss against fibre lateral displacement*

lateral displacement. The folded-path technique has been used to obtain simultaneously the joint-loss data as seen from both fibre ends, from which the true splice loss has been calculated by averaging (middle curve). Theoretical curves[5] using the Gaussian mode approximation have been fitted to the experimental points. The RMS deviation of the experimental values from the curves is only 0·016 dB. In this case the optimised joint loss was 0·07 dB. Note that for alignment purposes only the minimum loss position determined from either of the measurement directions gives the correct optimum alignment.

*Conclusions:* We have demonstrated a new and simple OTDR technique which enables absolute splice-loss data to be obtained from a single end of the fibre, and have shown that single-mode OTDR is an attractive means for providing active splice alignment information. It is thus envisaged that long-range single-mode OTDR will assume increasing importance as a tool for assisting cable installation.

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