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RF Reference Distribution for the LEP Energy Upgrade

L. de Jonge and J.P.H. Sladen

Abstract

The current LEP energy upgrade will include the installation of superconducting cavities in the LEP tunnel near interaction points P4 and P8. No copper cavities are present at these points and new optical fibre links have recently been installed to provide RF synchronisation. There are six new links with a total length of 16 km. They differ form those of the LEP Phase I system in that they contain both standard and temperature compensated single-mode fibres. The latter type of fibre is a relatively new development and its use results in a simplified synchronisation system. The layout of this system is described and results from long-term phase stability tests are given.

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CERN, Geneva, Switzerland

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The current LEP energy upgrade will include the installation of superconducting cavities in the LEP tunnel near interaction points P4 and P8. No copper cavities are present at these points and new optical fibre links have recently been installed to provide RF synchronisation. There are six new links with a total length of 16km. They differ from those of the LEP Phase I system in that they contain both standard and temperature compensated single-mode fibres. The latter type of fibre is a relatively new development and its use results in a simplified synchronisation system. The layout of this system is described and results from long-term phase stability tests are given.

Introduction

The copper RF cavities installed for LEP Phase I are located either side of interaction points P2 and P6. The RF phase reference signal is sent to these points from the main control room over single-mode optical fibre links. There are three links serving each point. One relatively long link is laid in a trench from the control room to a surface building situated at the interaction point. From there, two cables, each approximately 500m long, descend to the LEP klystron galleries either side of the interaction point.

For phase reference transmission, each link requires an elaborate feedback system in order to compensate for fibre delay variation due principally to climatic temperature changes. This system involves the use of a mirror to reflect part of the received light back down the fibre to the transmitting end where a phase shifter compensates for half the go and return delay variations. It has been described in detail elsewhere [1,2]. The six systems have been in constant use throughout the running of LEP. As well as for transmission of the RF phase reference, the links are used for the transmission of the bunch frequency and for returning diagnostic signals to the control room for monitoring. These links have no feedback compensation.

For the current energy upgrade of LEP [3], superconducting cavities will be added not only at P2 and P6, where the copper cavities are presently installed, but also at P4 and P8 where new RF accelerating stations are being created. For these latter two points, a new optical fibre transmission system has been installed. The lay-out of the links is identical to that of the LEP Phase I installation, i. e. there are two new cables laid in trenches from the control room to surface buildings at P4 and P8 and four new short links, each approximately 500m long, descending to the LEP klystron galleries. The principal difference to the earlier installation is in the use of a temperature compensated single-mode fibre.

The routes followed by the cables from the control room to the surface buildings at the interaction points are shown in Fig. 1, together with their lengths. These cables are laid at a depth of about 1m below ground level.

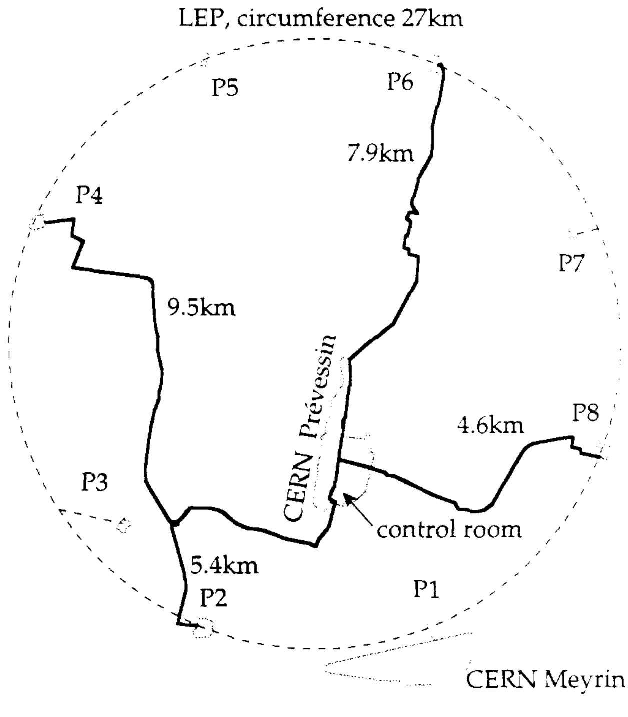

Fig. 1 Optical fibre cable routes for the LEP RF system.

Temperature compensated optical fibre links

Since the installation of the optical fibre links for the LEP Phase I RF system, a single-mode optical fibre cable has been developed with a very low thermal coefficient of delay [4]. The stabilisation is obtained by coating the silica fibre in a liquid crystal polymer having a negative thermal expansion coefficient. The magnitude of the thermal coefficient of delay of the coated fibre is specified as less than 0.4ppm/^{o}C between -10^{o}C and +25^{o}C. This compares with a value of about 7ppm for a standard bare fibre [5].

The use of this stabilised fibre offers advantages for RF reference distribution, fast timing distribution and diagnostics. The delay variations on the short links between the surface buildings and klystron galleries become negligible thus removing the need for feedback systems for RF reference transmission. This leads to a simpler, and hence more reliable, transmission system. Feedback will still be needed for the long links from the control room. However these are also simplified since the reduced phase variations remove the 180 degree phase ambiguity resulting from the feedback system [1, 2]. Consequently, transmission is at the LEP RF of 352MHz and not at 176MHz which is used for the links to P2 and P6.

The LEP revolution frequency generator (defining bucket number and controlling collision point) is situated in the control room. As the annual delay variations of the temperature stabilised fibre will be well under one RF period, one of these fibres can be used for transmitting this signal to the RF units for synchronising fast timing equipment, which presently runs on a local reference. Among other things, this will facilitate verification of correct collision point in case of synchronisation problems in LEP or its injectors.

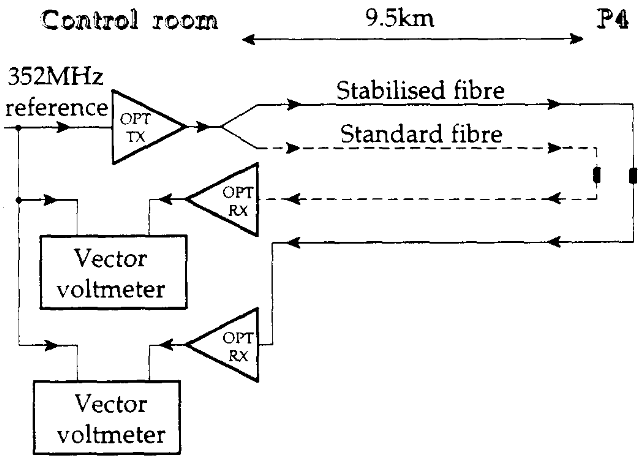

Fig. 2 Set-up for long-term phase stability tests.

Various signals can be selected in each RF station for transmission to the control room for diagnostic purposes. Transmission of these signals over temperature stabilised fibres will result in improved monitoring of RF station phases.

The cable employed for this project contains a total of twelve single-mode fibres of which five are temperature stabilised and seven are loosely buffered standard fibres.

Transmission equipment

The analogue optical fibre transmission equipment employed for the new links is similar to that used for the LEP Phase I system but has improved performance. The system bandwidth is 1kHz to 600MHz. A thermoelectrically cooled 1mW, 1300nm, Fabry-Perot laser was specially selected which was relatively insensitive to optical reflections. The strong reflection entering the laser in the links with optical feedback can give rise to unwanted phase variations. However, with this laser, no attenuator or isolator is required at the output to reduce this effect. The laser carrier-to-noise ratio is 110dB/Hz. The receiver incorporates a PIN diode and a transimpedance front-end amplifier. The carrier-to-noise ratio is 90dB/Hz for -30dBm optical input with 50% modulation depth.

Each transmitter and receiver chassis contains a number of alarms, e. g. laser temperature, laser bias, optical and electrical signal levels. These are connected to the control system via a computer interface and can be monitored remotely. There will be a total of 30 transmitters and 44 receivers in operation.

Long-term phase stability tests

Tests have been performed in order to verify the phase stability of the installed cable. The measurements were made on the longest cable (control room to P4), over twice its length. The set-up is shown in Fig. 2. Two stabilised and two standard fibres were joined at P4. The transmitting and receiving equipment was positioned in the control room and the phases of a 352MHz carrier transmitted over the stabilised and standard fibres were continually monitored between August 1993 and May 1994. No feedback phase compensation was employed during these tests. The results are shown in Fig. 3. The delay variation of the stabilised fibre is more than 20 times lower than that of the standard fibre. Fig. 4 shows the midday ambient temperature at CERN (not the cable temperature), averaged over seven days, during this period.

Because of the successful results of these tests, it has been decided to replace the existing short links at P2 and P6 with this temperature stabilised cable. The cable has now been ordered and installation is planned for the 94/95 winter shutdown.

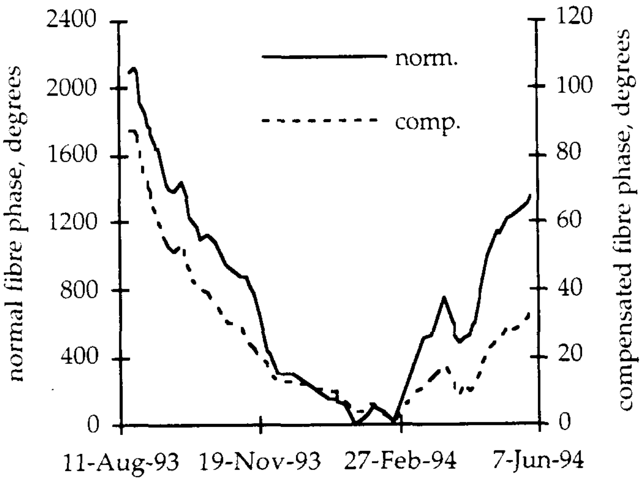

Fig. 3 Optical fibre cable phase stability results.

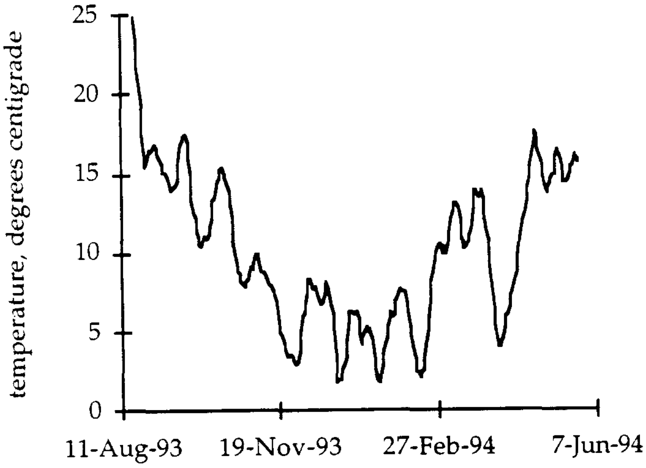

Fig. 4 Noon temperature, CERN, seven day average.

Acknowledgements

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