Commissioning the RF system of the SPring-8 storage ring

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1. Reference signal to RF stations

There are five RF stations in the SPring-8 storage ring as shown in Fig. 1. B-, C-, and D-stations are individually equipped with eight RF cavities resonating at 508.58 MHz. E-station is equipped with a master oscillator (a synthesizer, SMHU 58, ROHDE & SCHWARZ Co.) which generates a reference signal with a frequency of 508.58 MHz. Each RF station is connected to both of its neighboring RF stations with a cable having six phase-stabilized optical fibers. Deviations in the transmission time of the optical fibers are less than 5 ps/km/˚C at temperatures from 0˚C to 30˚C. An optical signal is modulated at the frequency of the reference signal by an electrical to optical transmitter (E/O) in the E-station. This optical signal is delivered to the RF stations and the synchrotron from the E-station through the optical fibers. A trigger signal with a frequency of 1 Hz synchronized with the reference signal is also delivered to the synchrotron and the linac [1][2].

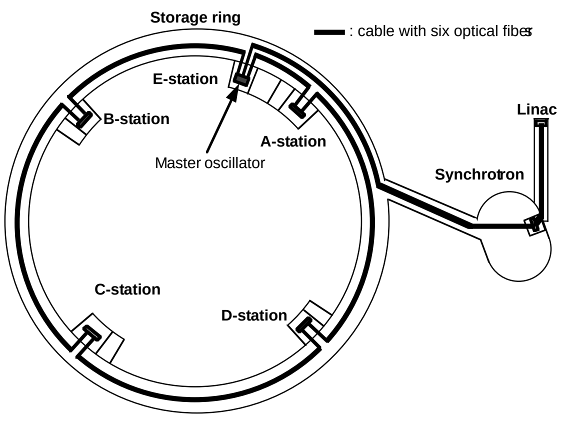

Fig.1 Connection diagram of cables with six phase-stabilized optical fibers.

The phase angles of the reference signal delivered to the three RF stations (B-, C-, and D-stations) were adjusted for synchronous beam acceleration while commissioning the storage ring [3]. Figure 2(a) shows a schematic diagram of a transmission system of the reference signal between the E-station and the B-station under the commissioning. The optical signal is, at first, sent to the B-station. A part of the optical signal is sent back to E-station by an optical reflector to lock the phase angle between the stations. A deviation in the phase angle of the reference signal between the stations is less than 2 deg. The deviation can be reduced to less than 1 deg by phase-lock loop feedback control (PLL). The electrical reference signal demodulated by an optical to electrical receiver (O/E) in the B-station is divided into two signals. One is used as a reference signal of the station. The other is sent to the next station. In the same way, the reference signal is sequentially delivered to the C- and D-stations.

At the beginning of the commissioning, the acceleration frequency was adjusted so that the number of beam revolutions would be maximized. The frequency for steady operation was 508.579670 MHz at which the horizontal closed orbit distortion was minimized. A rough phase angle of the acceleration voltage synchronous to a revolving beam could be obtained by finding the maximum number of beam revolutions in respective and independent operations of the RF stations. Moreover, a precise synchronous phase angle could be obtained by measuring the synchrotron frequency of the stored beam while driving all the RF stations. The phase angle between the storage ring and the synchrotron was adjusted so that the injection efficiency would be maximized and the horizontal beam oscillation just after beam injection from the synchrotron would be minimized.

After the commissioning and operations for five months, the transmission system shown in Fig. 2(a) was replaced with the simple system shown in Fig. 2(b) since the deviations in the phase angles between the stations were sufficiently small as expected and the amplitudes of the optical signals reflected by some of the optical reflectors were reduced unstably. In the revised transmission system, a bare deviation in the phase angle between the signal transmitted to B-station and the return signal from A-station was less than 6 deg. This deviation could also be reduced to less than 1 deg by PLL in the E-station.

2. Acceleration voltage

The delivered reference signal could be amplified up to 1 MW by a driving amplifier and a klystron. The total acceleration voltage by the 24 cavities in the three RF stations was set to 12 MV enough for a quantum lifetime. The acceleration voltage was calculated from signals picked up by calibrated monitor antennas installed in the cavities, calorimetric measurement values of the wall loss power of the cavities, and the synchrotron frequency [3].

The fundamental resonant mode of the cavities, the TM010-mode, was tuned at the frequency of the reference signal by tuner controllers with an offset in the phase angle of -5 deg to avoid Robinson instability.

Low-level controlling instruments locked the phase angle between the reference signal and the vector sum of the picked-up signals from the cavities with an error of less than 1 deg and kept the total acceleration voltage constant regardless of changes in the beam loading [4].

References

[1] Y. Kawashima et al., SPring-8 Annual Report, 164 (1996).

[2] H. Suzuki et al., Proc. of 11th Symposium on Accelerator Science and Technology, Hyogo (Japan), 80 (1997).

[3] T. Ohshima et al., Proc. of 11th Symposium on Accelerator Science and Technology, Hyogo (Japan), 95 (1997).

[4] Y. Ohashi et al., SPring-8 Annual Report, 161 (1996).

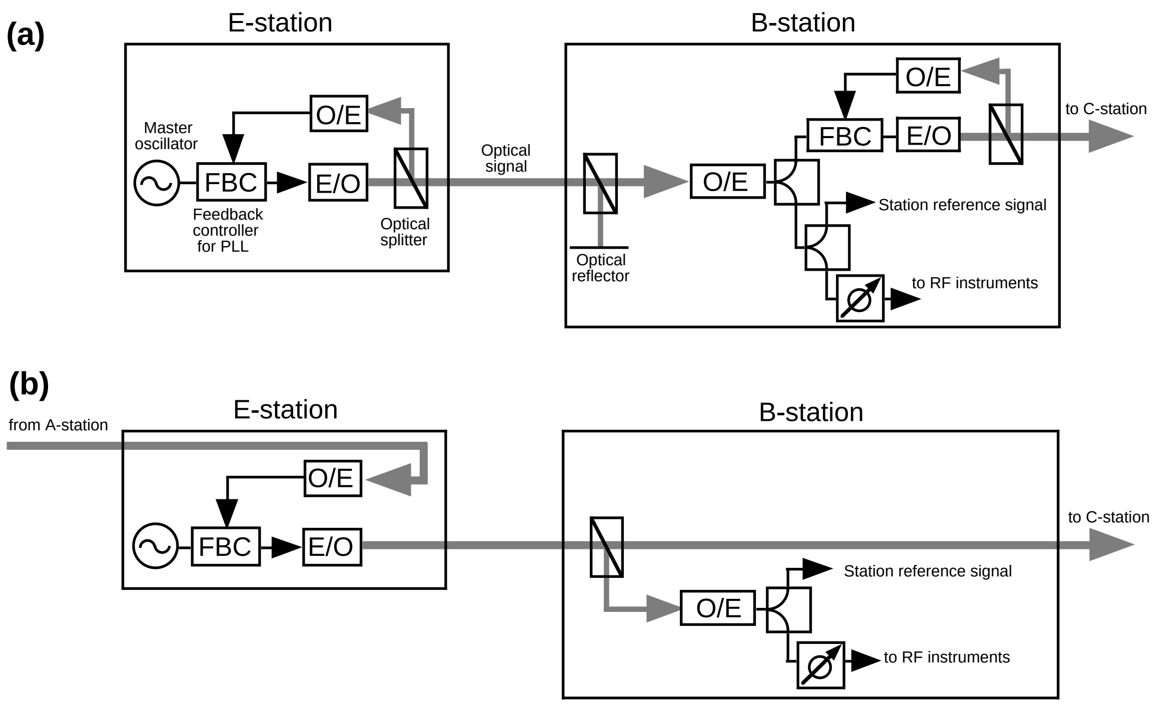

Fig.2 Schematic diagrams of a transmission system between the E-station and the B-station (a) while comissioning the storage ring (b) a revised one.