For each mode \( m \), \( m', \ldots \) there appears a family of frequencies in the beam:

\[
\begin{align*}
\omega_{\nu,m} &= \left( \nu_{\nu} \cdot 480 \pi \left( m + \nu_{m} \right) \right) f_{0}, \quad \nu_{\nu} = 0, \ldots, n_{\nu} \text{ fixed} \\
\omega_{\nu,m',m''} &= \left( \nu_{\nu} \cdot 480 \pi \left( m' + \nu_{m} \right) \right) f_{0}, \quad \nu_{\nu} = 0, \ldots, n_{\nu} \text{ fixed}
\end{align*}
\]

(1)

Summary

In the electron- and positron rings of DORIS strong transverse and longitudinal single beam instabilities were observed, which caused current limitations. The severest transverse and longitudinal instabilities were induced by excitation of higher modes in the rf-cavities. When these instabilities were cured by damping the higher cavity modes, the thresholds for this type of instabilities were greatly increased. The origin of the remaining transverse and longitudinal instabilities is not yet understood. The thresholds of these instabilities were increased by Landau-damping and changing the betatron- and synchrotron frequencies from bunch to bunch. The head-tail effect was observed at high peak currents and was cured by compensating the chromaticity.

In the electron ring a transverse instability is present which is induced by the ions. Ion clearing in combination with some vacuum improvements is sufficient to avoid this instability.

1. Cavity induced instabilities

The severest single beam instabilities observed in DORIS were induced by the excitation of higher parasitic modes in the rf-cavities. Except for a very short filling of the ring (10 to 20 bunches) the current limitation was nearly independent of the circumferential distribution of the bunches, so that mainly the mean currents were limited. The thresholds for the transverse and longitudinal instabilities appeared in the range of 1 to 5 mA. However, the thresholds and the maximum currents, that could be stored were strongly correlated to the tune of the cavities in each ring, so that by varying the tunes of the cavities at random 200 mA could be stored or even more.

It turned out, that the transverse instabilities were induced by higher deflecting modes of the rf-cavities, while the longitudinal instabilities were induced by higher accelerating modes.

After improvement of the detecting equipment rf-signals from the beam picked up from wide-band electrodes in the rings and from loops in the cavities, were spectrum analysed.

In the beam and in the cavities we found higher-mode-frequency signals, coincident with the excitation of instabilities.

In order to identify the higher cavity modes causing the instabilities a special program of mode spectroscopy was started, based on the following properties of the beam:

the homogeneously filled beam of 480 bunches can oscillate in \( 480 \) states (modes) \( m \) for each the transverse

\[ m_{\nu} = 0, \ldots, 479 \]

and the longitudinal case

\[ m_{\mu} = 0, \ldots, 479 \]

For each mode \( m \), \( m' \) there appears a family of frequencies in the beam:

\[
\begin{align*}
\omega_{\nu,m} &= \left( \nu_{\nu} \cdot 480 \pi \left( m + \nu_{m} \right) \right) f_{0}, \quad \nu_{\nu} = 0, \ldots, n_{\nu} \text{ fixed} \\
\omega_{\nu,m',m''} &= \left( \nu_{\nu} \cdot 480 \pi \left( m' + \nu_{m} \right) \right) f_{0}, \quad \nu_{\nu} = 0, \ldots, n_{\nu} \text{ fixed}
\end{align*}
\]

(1)
ii) longitudinal instabilities were excited by higher accelerating modes: TM011 (740 MHz), TM022 (1200 MHz), TM022 (1585 MHz and modes above 1800 MHz).

Since it was not possible to operate the cavities in a reproducible way avoiding dangerous modes, there was need for damping the exciting cavity modes keeping the influence on the fundamental mode small. For this purpose special water-cooled radial antennae were developed which couple to the transverse electric field of the modes. The energy is transferred to a coaxial system where it is absorbed by iron material with a high permeability. Two absorbing systems work for each cavity and modes with transverse electric fields can be damped down by a factor 2000. The TM110-mode (no transverse electric field) is still present, however, we avoid crossing this mode by a proper cavity tuning during control. Above 1200 MHz the modes begin to propagate in our chamber. We put ferrite material in the chamber between the cavities for an over all damping of all these modes.

2. Transverse "multi-modes"

When it was possible to accumulate higher currents - after the cavity modes had been damped - transverse instabilities appeared again and limited the currents. These instabilities increased the horizontal and vertical beam size and depending on the optics - limited currents to values between 150 and 300 mA. The instabilities occurred in coincidence with about 15 betatron oscillation lines density spaced around the multiples of the radio frequency \(480f_B = 499.666 \text{ MHz}\). These instabilities caused a mean current limitation. Using octupole magnets we can increase the "multi-mode" threshold from 20 to 70 mA. An rf-quadrupole which works on the 15th harmonic of the revolution frequency and provides a maximum Q-split of 0.03 can increase the threshold by a factor 6, so that we can reach about 450 mA without an increase of the beam size due to the "multi-mode" instability. The interaction mechanism of this instability is not yet understood.

3. Head-tail effect

Head tail instabilities limited the average current to 0.25 mA/bunch. After over-compensating the negative chromaticity with sextupole magnets to small positive values we reached 15 mA/bunch at 2 GeV.

4. Longitudinal instabilities

At higher currents (> 200 mA) longitudinal instabilities appear which at present seem to limit the luminosity due coherent and incoherent bunch lengthening. At the moment we do not know, whether these instabilities are connected with higher cavity modes which are not sufficiently damped.

We can reduce the influence of these instabilities on the luminosity by splitting the synchrotron frequencies from bunch to bunch operating one of our two transmitters in each ring on the 48st harmonic of the revolution frequency.

5. Ion instabilities

In the electron ring we observed a transverse (mainly vertical) instability which disappeared when the electrodes for ion clearing were put to 10 KV and a gap (10 %) in the circumferential ring filling was present. As the vacuum improves this instability is not important.

References