horizontal tune remains unchanged at $\upsilon_x = 4.748$.

The result from the beta function matching is, however, not satisfactory. Despite the symmetry being restored, the new vertical tune is dangerously closed to the integer resonance. We next investigate the betatron tune matching. Using similar procedure, but the qudrupole strengths are now adjusted to match the perturbed betatron tunes to the unperturbed values. It is noted that since adjusting the strengths of the qudrupole magnets disturbs the electron motion in both planes, the horizontal tune has to be included in the matching constraints. From the calculations, by decreasing the strengths of the focusing quadrupole pair by 1.23% and of the defocusing quadrupole pair by 4.56% the vertical and horizontal tune shifts are kept to within $\Delta\upsilon_y = 0.004$ and $\Delta\upsilon_x = 0.003$, respectively. In this case, however, the symmetry of the storage ring is still broken badly, as shown in Figure 8.

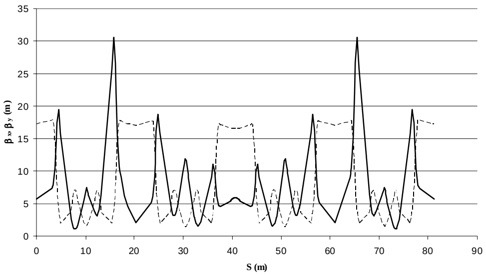

Fig 8. Calculated vertical (solid line) and horizontal (broken line) beta functions for the SPS storage ring, with the wiggler. The betatron tunes are fitted to the unperturbed values.

At the last step we make an attempt to compromise between restoring the symmetry and the betatron tunes. This matching is carried out by allowing additional two further pairs of quadrupole magnets, one focusing pair and one defocusing pair, adjacent to the two previous pairs, to be adjusted. It is, however, found to be difficult to achieve the perfect compensation. The best result obtained is by increasing the strengths of the first quadrupole pair by 0.74%, decreasing the second pair by 0.23%, decreasing the third pair by 0.13% and decreasing the fourth pair by 8.60%. This compensation scheme keeps the betatron tune shifts to within $\Delta\upsilon_y = 0.009$ and $\Delta\upsilon_x = 0.004$. The symmetry is , however, not perfectly restored, as shown in Figure 9. Nevertheless, the storage ring is expected to be operational in this condition. Other possibilities for compensation may be further investigated. This includes moving the operation tunes to other values altogether, which will give more flexibility for compensation. Another option is to install additional quadrupole magnets at both ends of the wigglers. These options, however, need further comprehensive studies. Furthermore, in a real device there will be small contributions from additional multipole field components arising from imperfection of the magnetic arrangement and inhomogeneous field distribution within the magnets. These small multipole components can be accurately identified via high precision magnetic measurements. More detailed studies can then be carried out to compensate such errors.

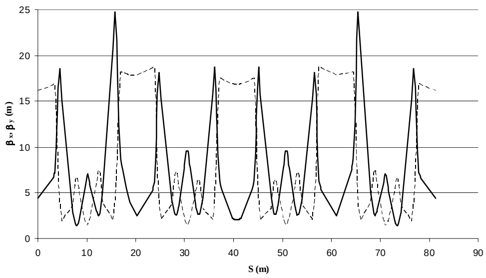

Fig 9. Calculated vertical (solid line) and horizontal (broken line) beta functions for the SPS storage ring, with the wiggler. The betatron tunes and beta functions are fitted to the unperturbed values.

Conclusions

We have presented a case study of effects of a high field insertion device on the SPS storage ring. The oscillating magnetic field of the device is simulated from series of permanent magnets, allowing random errors of the magnetization. The wiggler focusing strength is calculated from the simulated magnetic field. The vertical betatron tune shift and stop-band width resulting from perturbations of the wiggler are evaluated and found significant. Compensation schemes to restore the storage ring symmetry and correct the tune shift are presented. The studies carried out in this report can be easily applied to other types of insertion devices to be installed in the SPS in the future.

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