## IR Optics

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## Tow Options

- High current, crab crossing, large beambeam parameter.
- A solution for $\beta^{*} x=20 \rightarrow 40 \mathrm{~cm}$
- Low emittance, low $\beta^{*}$, nano-beam.
- Just started.
- Crossing angle $30 \rightarrow 60$ mrad


## High Current Option

 SuperKEKB machine parameters|  |  | LER | HER |  |
| :---: | :---: | :---: | :---: | :---: |
| Emittanc | $\varepsilon_{x}$ | 24 | 18 | nm |
| Emitance | $\varepsilon_{y}$ | 0.24 | 0.09 | nm |
| Beta at IP | $\beta_{\mathrm{x}}{ }^{*}$ | 20 | 20 | cm |
| Beta at IP | $\beta_{y}{ }^{*}$ | 3 | 6 | mm |
| Bunch length | $\sigma_{7}$ | 5 | 3 | mm |
| Betatron tune | $v_{x} / v_{y}$ | .505/.5905 | .505/.5905 |  |
| Synchrotron tune | $v_{\text {s }}$ | 0.025 | 0.025 |  |
| Beam current | $\mathrm{I}_{+} / \mathrm{I}_{-}$ | 9.4 | 4.1 | A |
| \#bunches/harmonic\# | $\mathrm{N}_{\mathrm{b}} / \mathrm{h}$ | 5018/5120 |  |  |
| Crossing angle | $2 \phi_{x}$ | $30 \rightarrow 0$ (crab crossing) |  | mrad |
| Beam-beam*1 | $\xi_{x}$ | 0.182 | 0.138 |  |
|  | $\xi_{y}$ | 0.295 | 0.513 |  |
| Damping | $\mathrm{T}_{\mathrm{x}}$ | 6000 | 4000 | turns |
|  | $\mathrm{T}_{\mathrm{y}}$ | 6000 | 4000 | turns |
|  | $\mathrm{T}_{\mathrm{e}}$ | 3000 | 2000 | turns |
| Luminosity | L | $5.3 \times 10^{35}$ |  | $\mathrm{cm}^{-2} \mathrm{~s}^{-1}$ |

K. Ohmi
Y. Funakoshi
*1: ignore effects of traveling focus

## Large Dynamic Effects

- The beam-beam effect must be taken into account in evaluation of physical apertures.
- Horizontal beam parameters change significantly with $\xi_{x 0}=0.276$ and $v_{x}=.505$,
$-\beta_{x}{ }^{*} 20 \rightarrow 1.9 \mathrm{~cm}$
- $\varepsilon_{\mathrm{x}} 12 \rightarrow 65 \mathrm{~nm}$
Y. Funakoshi

Example: HER $B X^{*} / B Y^{*}=20 / 0.5 \mathrm{~cm}$



## Physical Aperture

- Requirement : $5 \sigma_{x}$ with beam-beam effect
- Larger than injection aperture.
- $\quad \sigma_{x}$ must be decreased at QC2LE (HER) and QC2RE (HER).
- SR fan from $3 \sigma_{x}$ and $3 \sigma_{x^{\prime}}$ should also be considered.
- Increased $\beta_{x} * 20 \rightarrow 40 \mathrm{~cm}$
- Luminosity will decrease by ~20 \%.



## Injection Acceptance

- Injection acceptance is evaluated:
- HER/LER 4.5E-6/7.5E-6 m w/o Damping Ring
- HER/LER 1.9E-6/2.6E-6 $\rightarrow \sim 1.0 \mathrm{E}-6 \mathrm{~m}$ with Damping Ring


M. Kikuchi


## Optics with New Quads

- To reduce $\beta x^{*} 40 \rightarrow 20 \mathrm{~cm}$ again with new quads.
- 1.9 K superconducting and permanent quads.
- Additional horizontal focusing quads for HER.
- At present, only L-side is acceptable from the view point of $\sigma_{x}$ and SR fan.



## Present Layout



## LER Optics

- $\beta x^{*}$ is still 40 cm , which is limited by R -side.
- Only L-side with a new superconducting quadrupole.
- Field gradient of QCS's is optimized for LER.



## HER Optics

- Only L-side with new quadrupoles.
- Additional horizontal focusing quad (permanent) is introduced.

IR: $B X * / B Y^{*}=40 / 0.5 \mathrm{~cm}$


Tsukuba: $B X * / B Y *=40 / 0.5 \mathrm{~cm}$




## Low Emittance Option

|  | Parameters for Super B Factories |  |  | a) b-b simulation, b) geometrical |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | SuperKEKB | SuperBunch T | SuperBunch H | Super B | Super B New |
| $\varepsilon x(\mathrm{~nm})(\mathrm{L} / \mathrm{H})$ | 24/18 | $1 / 10$ | 1/10 | 2.8/1.6 | 2.8/1.6 |
| عy(nm) | 0.24/0.09 | 0.0035/0.025 | 0.0035/0.025 | 0.007/0.004 | 0.007/0.004 |
| $\kappa(\%)$ | 1/0.5 | 0.35/0.25 | 0.35/0.25 | 0.25/0.25 | 0.25/0.25 |
| $\beta x$ (mm) | 200/200 | $35 / 20$ | 35/10 | 35/20 | 44/25 |
| $\beta y$ (mm) | 3/6 | $0.35 / 0.22$ | 0.35/0.22 | 0.22/0.39 | 0.21/0.37 |
| $\sigma x(\mu \mathrm{~m})$ | 69/60 | 5.9/14 | 5.9/10 | 9.9/5.66 | 11/6.32 |
| $\sigma \mathrm{y}(\mu \mathrm{m})$ | 0.85/0.73 | 0.035/0.071 | 0.035/0.071 | 0.039/0.039 | 0.038/0.038 |
| $\sigma z(\mathrm{~mm})$ | 5/3 | 6/6 | 6/6 | 5/5 | 5/5 |
| $\phi \sigma z / \sigma x$ | 0/0 | 31/13 | 31/18 | 14/25 | 14/24 |
| $\sigma x / \phi(\mathrm{mm})$ | $\infty / \infty$ | 0.21/0.47 | 0.20/0.33 | 0.35/0.20 | 0.37/0.21 |
| ne | $5.25 \times 10^{10}$ | $3.89 \times 10^{10}$ | $8.11 \times 10^{10}$ | $5.52 \times 10^{10}$ | $5.99 \times 10^{10}$ |
| np | $12 . \times 10^{10}$ | $6.78 \times 10^{10}$ | $1.39 \times 10^{11}$ | $5.52 \times 10^{10}$ | $5.99 \times 10^{10}$ |
| $\mathrm{I}_{\text {beam }}(\mathrm{A})$ | 9.4/4.1 | 2.70/1.55 | 2.65/1.55 | 1.85/1.85 | 2.0/2.0 |
| \#bunch/Cir(m) | 5000/3016 | 2500/3016 | 1200/3016 | 1251/1800 | 1251/1800 |
| $\phi$ (mrad) (half crossing angle) | 0 | $30$ | 30 | 24 | 30 |
| $\xi \mathrm{y}$ | 0.30/0.51 | 0.067/0.068 | 0.139/0.139 | 0.147/0.150 | 0.125/0.126 |
| Lum | $5.3 \times 10^{35}$ a) | $5.0 \times 10^{35}$ b) | $10 \times 10^{35}$ b) | $11 \times 10^{35}$ b) | $10 \times 10^{35}$ b) |

## Italian version of IP

- $B X^{*} / B Y^{*}=20 / .200 \mathrm{~mm}$




## Italian version of IP

- Dynamic aperture

A. Morita


## Summary

- For high current option, we have not yet found a realistic solution of $\beta_{x}{ }^{*}=20 \mathrm{~cm}$. At present, $\beta_{x}{ }^{*}$ remains 40 cm .
- Design of low emittance option has just started.
- Geometry of IR beam lines
- New layout with 60 mrad crossing angle


## Beam size @ IR Q-magnets

$$
v_{x}=.505
$$

$$
\text { (): } 5 \sigma_{x}
$$

|  | QC1.E | QC2LE | QC1RE | QC2RE | 0C2LP | QC2RP |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{aligned} & \mathrm{b}_{\mathrm{x}}^{*}=20 \mathrm{~cm} \\ & \text { QC2RE: } \end{aligned}$ | $\begin{gathered} 8.2 \\ (41) \end{gathered}$ | $\begin{gathered} 26.9 \\ (134.5) \end{gathered}$ | $\begin{aligned} & 11.6 \\ & (58) \end{aligned}$ | $\begin{gathered} 28.8 \\ (144) \end{gathered}$ | $\begin{gathered} 14.7 \\ (73.5) \end{gathered}$ | $\begin{aligned} & 18.6 \\ & (93) \end{aligned}$ |
| $\begin{aligned} & b_{x}^{*}=20 \mathrm{~cm} \\ & \text { QC2RE->IP } \end{aligned}$ | $\begin{gathered} 8.4 \\ (42) \end{gathered}$ | $\begin{aligned} & 19.0 \\ & (95) \end{aligned}$ | $\begin{aligned} & 12.0 \\ & (60) \end{aligned}$ | $\begin{gathered} 20.7 \\ (103.5) \end{gathered}$ |  |  |
| $\begin{aligned} & b_{x}^{*}=40 \mathrm{~cm} \\ & \text { QC2RE->IP } \end{aligned}$ | $\begin{gathered} 5.9 \\ (29.5) \end{gathered}$ | $\begin{aligned} & 13.4 \\ & (67) \end{aligned}$ | $\begin{gathered} 8.5 \\ (42.5) \end{gathered}$ | $\begin{aligned} & 14.6 \\ & (73) \end{aligned}$ | $\begin{gathered} 9.8 \\ (49) \end{gathered}$ | $\begin{gathered} 12.3 \\ (61.5) \end{gathered}$ |


|  |  | QC1LE | QC2LE | QC1RE | QC2RE | QC2LP | QC2RP |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Field gradient | $\mathrm{T} / \mathrm{m}$ | 15.5 | 3.4 | 12.0 | 8.8 | 6.7 | 3.4 |
| Pole length | m | 0.64 | 2.0 | 0.75 | 0.8 | 0.6 | 1.0 |
| b bore radius | mm | 25 | 50 | 48 | 90 | 80 | 40 |
| Current | AT | 3920 | 3400 | 11050 | 28400 | 17100 | 1980 |
| coil turns <br> Current density of | /pole | 3 | 8 | 3 | 16 | 15 | 3 |
| Septum conductor <br> Field in the area for <br> couter-circulating beam | $\mathrm{A} / \mathrm{mm}^{2}$ | 30 | 10 | 70 | 24 | 31 | 15 |

Table 3.3: Parameters of special quadrupole magnets

