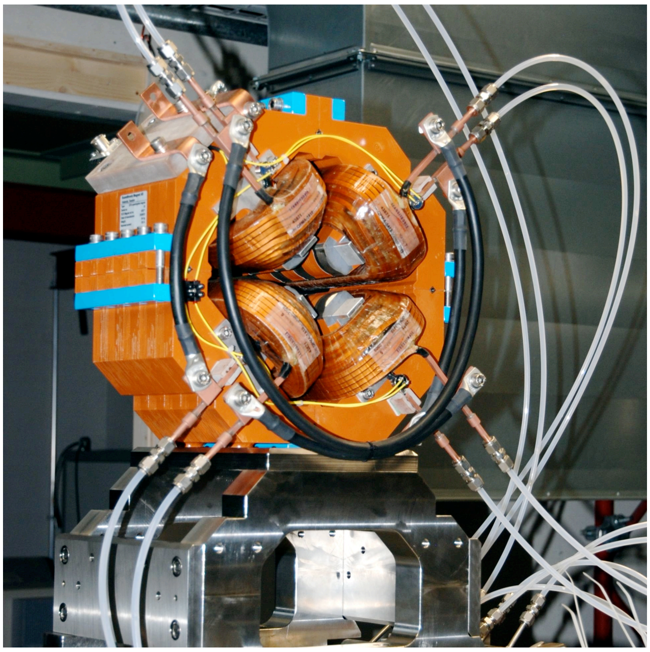
QFA Quadrupoles (SwissFEL 250 MeV Injector)



QFA quadrupole (#2 of 28)

2R = 45 mm

L = 150 mm

45 turns/coil

I_{MAX} = 150 A

MEASUREMENT DATE:
3 June–31 July 2009

MEASUREMENT ARM:
aluminum block standard interface
titan pipe Ø 33.4/25.6/12.8 mm

MEASURING SPEED:
4.5 mm/sec (X-axis)
25 mm/sec (Z-axis)

INTEGRATION TIME:
20 msec

DVM-1 (1 V RANGE):
Hall probe sbv1884 (400 mA)

DVM-2 (10 V RANGE):
50 V / 200 A (MSG-2.1), 1 A/s

AIR CONDITIONING:
OFF (T_{LAB} = 23.9°–28.2°)

OPERATORS:
Roland Deckardt
Natalia Głowa
Vjeran Vranković (report)

DATA DIRECTORY:
afs: sys/alpha_dux51/swdir/
magnet/meas/qfa

Alignment and Positioning for Hall Probe Measurements

The magnets mounted on their supports were placed on adjustable base plate. The base plate can be leveled by adjusting its feet heights.

In the measurements coordinate system the quadrupole axis is the Z-axis, vertical axis is the Y-axis. The quadrupole center is at the origin of the coordinate system.

The aligning and positioning of the quadrupoles were done magnetically by measuring horizontal field maps of the double reference pin, a permanently magnetized conically shaped iron piece, that was inserted in each of 4 designated holes on the top of the magnets. A two-dimensional quadratic polynomial is fitted to the measured data. Because the strongest magnetic field is at the tip of the pin, the position of the fit maximum corresponds to the pin tip and therefore to the hole position.

The horizontal (rotation around Y-axis) and vertical inclination (rotation around X-axis) of the quadrupoles were adjusted until all the positions corresponded to the coordinates from the manufacturer's report (there were some discrepancies between our measurements and the report).

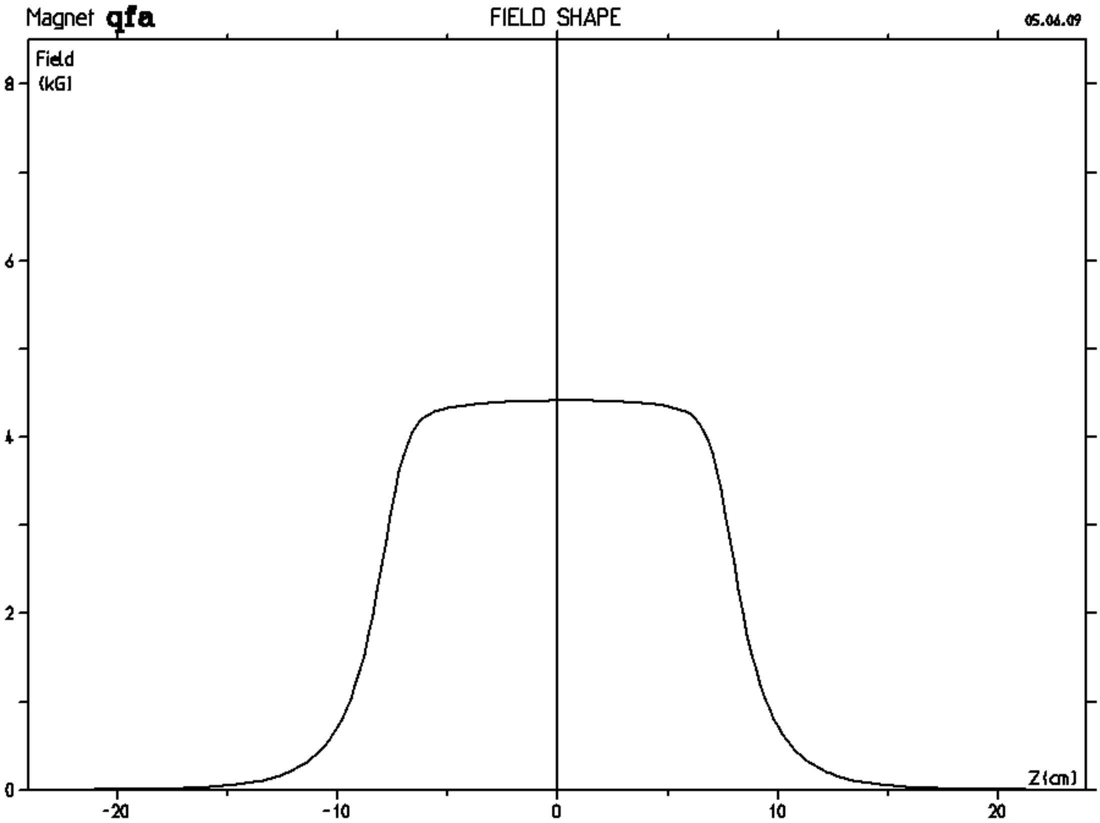
Alignment and Positioning on the Rotating Coil Bench

The magnets with their support were placed on the side bench with two cross tables allowing for movements in X and Y at both ends of the rotating coil shaft. The shaft was inserted in the magnets and its middle part laid on 1.75 mm thick half cylinder aluminum spacer positioned on two bottom poles.

The shaft's outer diameter is 41.5 mm, and the magnet aperture 45.0 mm. Therefore the shaft centre was in the middle of the magnet poles with a positioning error of less than 0.1 mm.

Field Analysis

The field $B_Y(z)$ of the quadrupole QFA-2 (X=14mm, Y=0) is shown. The current is 150 A.



The fieldmaps were measured with both current polarities ±150 A, in order to remove the earth and the background fields from the measured fields:

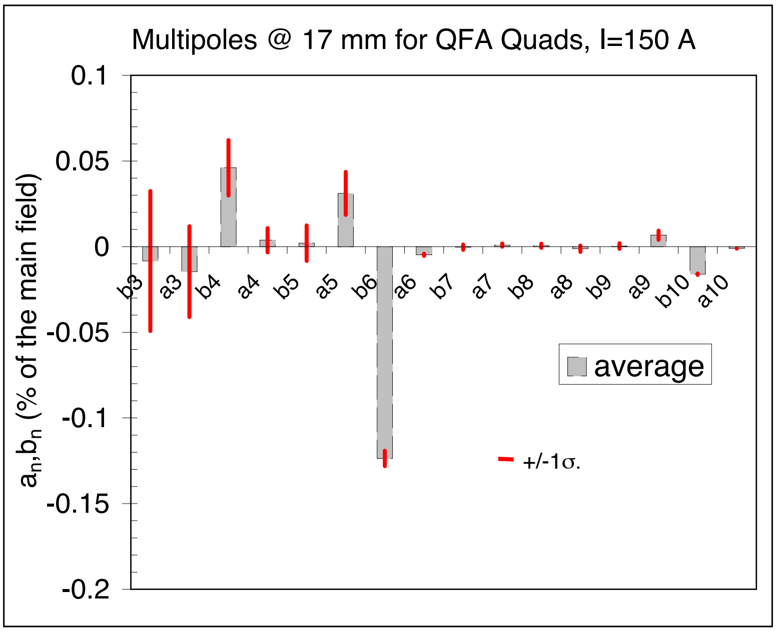
$$\frac{measurement(+current) - measurement(-current)}{2}$$

With the "least squares" method the slope and the intersection of a line that best fits the field integrals $B \cdot dz$ in the region of X=±14 mm was found. The slope equals to the integrated gradient $g \cdot dz$ or to the quadrupole strength.

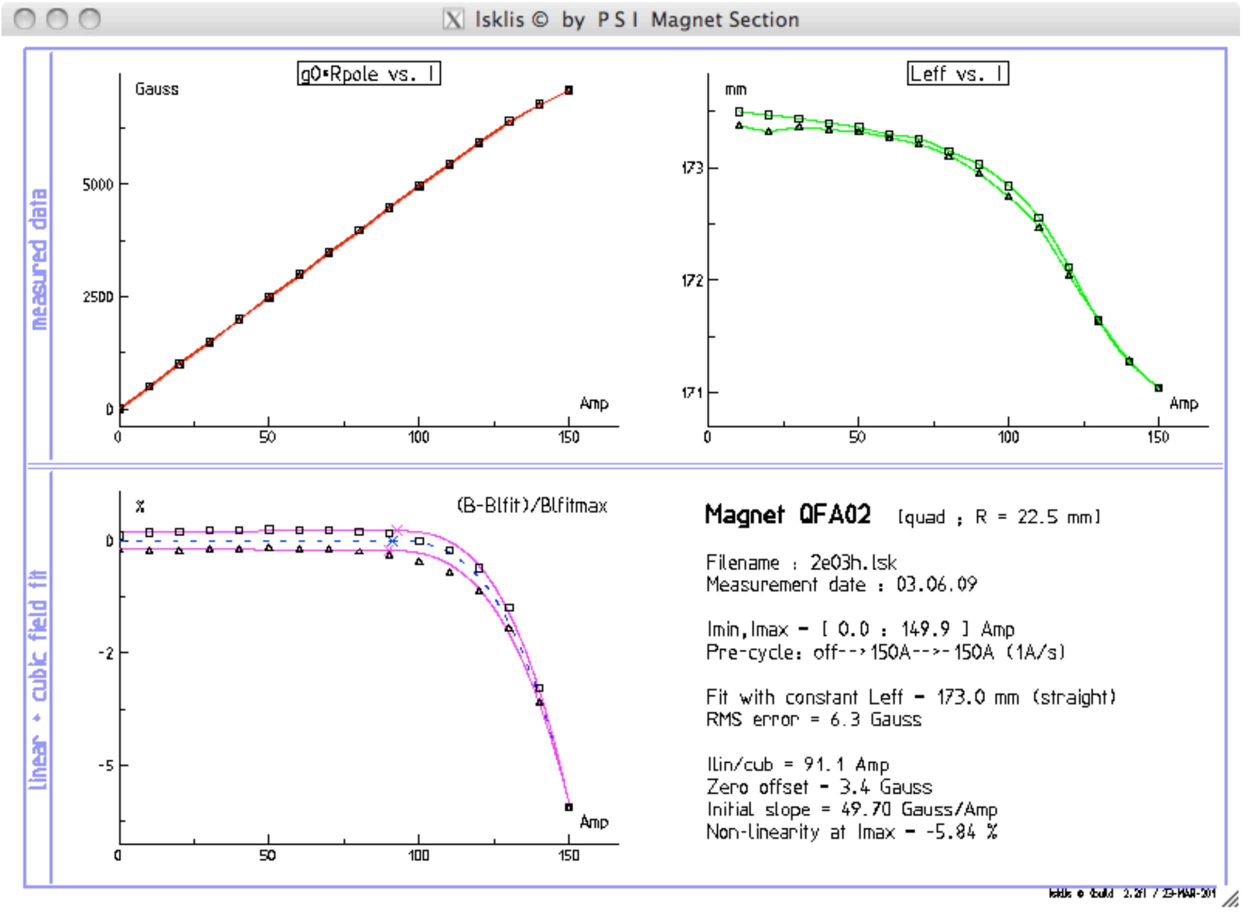
Integrated gradient has been measured with the rotating coil on all quadrupoles and with the Hall probe on 3. The summary of the results (at I=150A) is shown in the next table.

QFA (150 A)	**g·dz** [Gauss]	**with Hall probe**	**ΔX** [mm]	**ΔY** [mm]
1	54286.9		-0.08	0.26
2	54323.9	53963.1 (99.34%)	-0.05	0.42
3	54358.6		-0.01	0.30
4	54346.5		0.23	0.50
5	54288.4		-0.05	0.20
6	54441.9		0.20	0.62
7	54284.6		0.04	0.42
8	54289.0		0.09	0.54
9	54341.7		-0.02	0.23
10	54361.6		0.13	0.64
11	54284.2	53885.2 (99.27%)	0.16	0.53
12	54401.3		0.18	0.65
13	54239.5		-0.13	0.23
14	54355.8		0.10	0.39
15	54219.6		0.12	0.49
16	54213.0		0.20	0.62
17	54348.1		-0.02	0.39
18	54214.7		0.08	0.23
19	54189.1		0.03	0.31
20	54237.6	53960.7 (99.49%)	0.10	0.54
21	54200.2		0.01	0.32
22	54227.8		0.01	0.48
23	54241.3		-0.11	0.23
24	54264.9		0.18	0.46
25	54228.0		0.05	0.29
26	54262.9		-0.02	0.45
27	54168.9		0.02	0.18
28	54313.4		0.09	0.37

The average integrated gradient (at I=150 A) is 54283.3 Gauss. If we take for the magnetic effective length a value of 171 mm then the average gradient is 317.4 Gauss/mm or 31.74 T/m.



Excitation curve



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Magnet QFA02

File : 2e03h.lsk
Date : 03.06.09

Pre-cycle : off-->150A-->-150A (1A/s)

#Curr: 31 (nPaths=2)
Z-dir: from -400.00 mm, steps of 2.00 mm
X-dir: at -15.00 mm & at 15.00 mm
Rpole: 22.50 mm

 linear_<1:Ilin> and cubic_<Ilin:Imax> approximation of Bp:
 Blin = b0 + b1 * Irel                      ;   Irel = I / Imax
 Bcub = Blin + b2 * Irel^2 + b3 * Irel^3    ;   Irel = (I - Ilin) / (Imax - Ilin)

       Ilin_A     Imax_A      b0_G       b1_G       b2_G       b3_G      RMS_G
       ======     ======      ====       ====       ====       ====      =====
 /       89.8      149.9     -11.1     7449.3      -88.8     -328.9        6.1
 \       92.7      149.9      17.8     7455.0      -81.9     -371.6        6.5
 ¯       91.1      149.9       3.4     7452.2      -81.3     -354.2        6.3

 / = increasing current branch
 \ = decreasing current branch
 ¯ = average

constLeff (straight) = 173.0 mm

   I_Amp          gdz_G      Bp_G     err_G
   =====          =====      ====     =====
    0.00*         -92.7     -12.1      -1.0
   10.00/        3715.4     483.2      -2.5
   20.00/        7543.3     981.1      -1.4
   29.99/       11379.9    1480.0       1.3
   39.99/       15205.4    1977.6       2.0
   49.99/       19031.5    2475.2       2.9
   59.98/       22841.4    2970.7       2.1
   69.98/       26655.7    3466.8       1.4
   79.98/       30449.2    3960.2      -2.0
   89.97/       34223.1    4451.0      -7.5
   99.97/       37965.1    4937.7     -13.4
  109.97/       41647.1    5416.5     -13.1
  119.96/       45232.2    5882.8      -1.7
  129.96/       48567.6    6316.6       9.0
  139.96/       51454.3    6692.0       2.7
  149.95*       53931.1    7014.2      -5.7 (average of 2 fits)
  139.96\       51622.4    6713.9       2.7
  129.96\       48835.2    6351.4       9.7
  119.96\       45511.0    5919.1      -4.0
  109.97\       41926.9    5452.9     -14.5
   99.97\       38221.1    4971.0     -14.9
   89.97\       34493.5    4486.2      -4.7
   79.98\       30696.7    3992.3      -1.8
   69.98\       26896.1    3498.0       1.1
   59.98\       23083.3    3002.2       2.3
   49.99\       19269.0    2506.1       2.9
   39.99\       15436.5    2007.6       1.7
   29.99\       11612.8    1510.3       1.5
   20.00\        7778.6    1011.7      -0.5
   10.00\        3948.8     513.6      -1.4
    0.00*          92.7      12.1      -5.8

   Bp = gdz / constLeff * Rpole
   err = Bp - Bfit
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