21.07.97.

Modeling Fields of the FEL Steering Coils by means of Additional magnets of the code ELOP

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a)

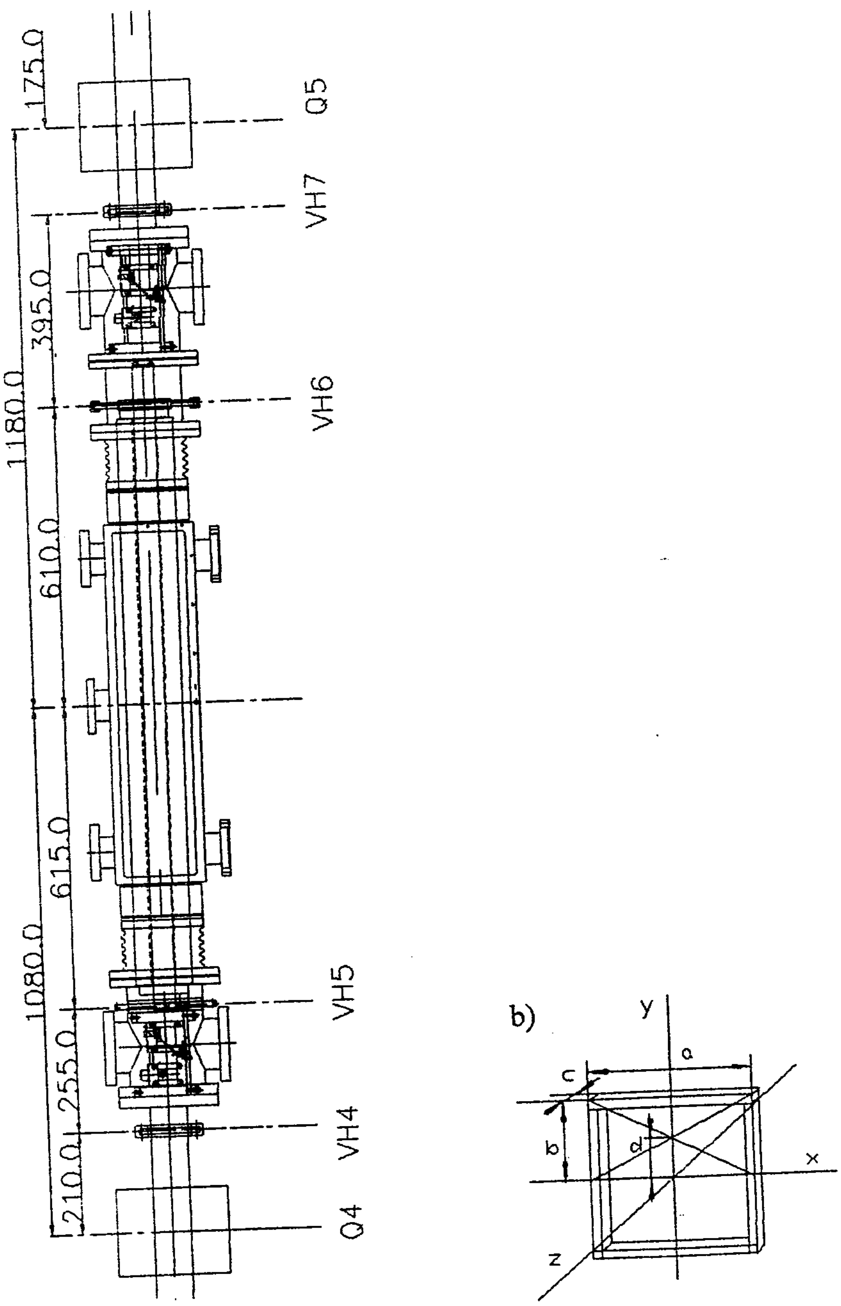

Fig1. a). Central part of the TAU FEL. Q4, Q5 - Quadrupoles, VH4, VH5, VH6, VH7 - steering coils (or their axis). b). Geometry of steering coils.

1. UCLA-type Steering coil (VH4, VH7)

1.1. Two blocks model

Table 1.

UCLA-type steering coil parameters

	a	b	c	d	φ, deg	Bs, Gs
1.	123.5	50.75	11	25.375	0	4662.75
2.	101.5	50.75	11	25.375	180	4662.75

$\int_z B_y^{exp} dz=2452$ Gs mm; $\int_z B_y^{sim} dz=3034$ Gs mm; $\delta= \int_z B_y^{exp} dz - \int_z B_y^{sim} dz = -19.2\%$

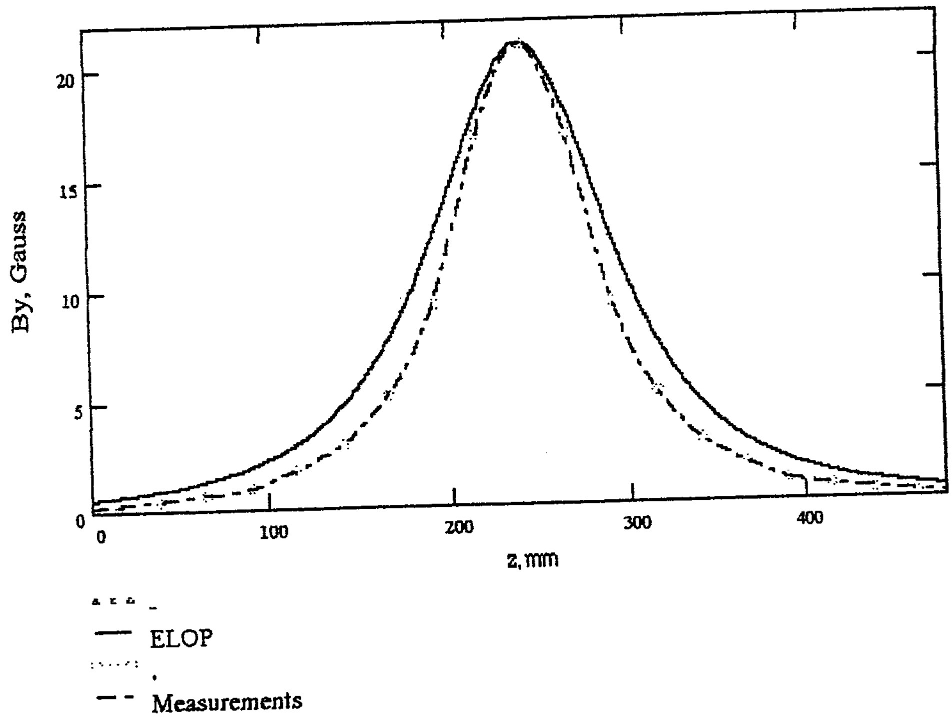

Fig.3. Two-block model for UCLA-type steerings (Table 1).

This is a bad fit therefore we will try a three block model.

1.2. Three blocks model of the UCLA-type magnet

Table 2.

UCLA-type steering coil parameters

	a	b	c	d	φ, deg	Bs, Gs
1.	123.5	50.75	11	25.375	0	1193.63
2.	101.5	50.75	11	25.375	180	1193.63
3.	123.5	11.	11.	56.25	180	1193.63

$\int_z B_y^{exp} dz$=2429 Gs mm; $\int_z B_y^{sim} dz$=1569 Gs mm; δ= 33.0%.
Experiment: $B_y(0)$=21Gs for I=1.6A.

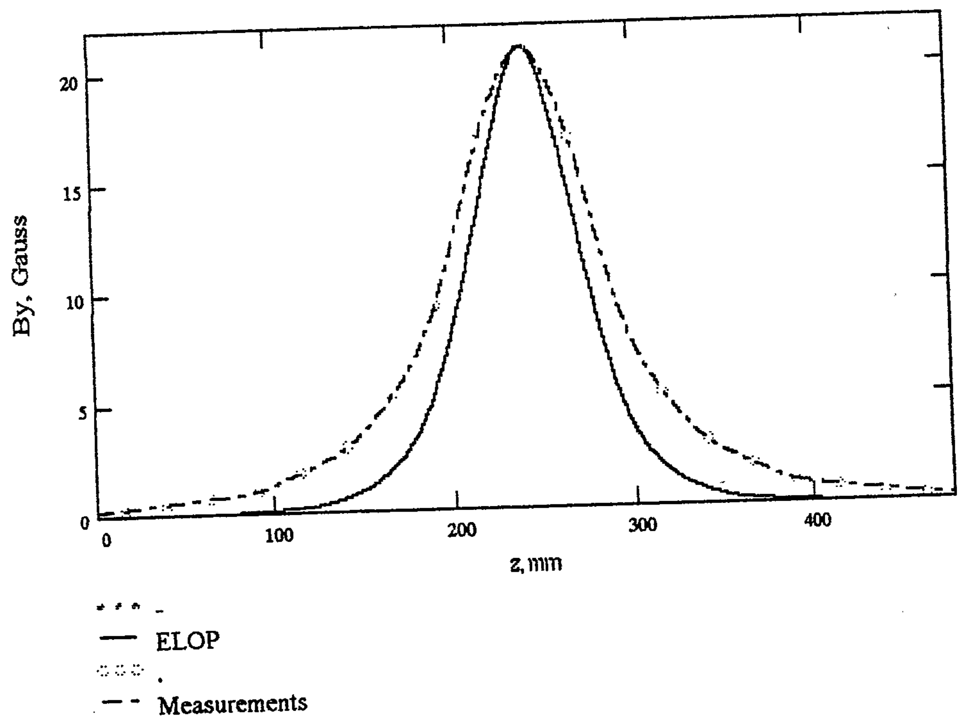

Fig.4. Three blocks model of the UCLA-type magnets (Table 2).

This is still a bad hit. Therefore we will relieve the model by changing the relative strength of magnet number 3.

2. Field optimization.

2.1. UCLA-type coil. (VH4,VH7)

Table 3.

UCLA-type steering coil parameters after optimization of the ratio betveen the strengths of magnets 1, 2 and 3.

	a	b	c	d	φ, deg	Bs, Gs
1.	123.5	50.75	11	25.375	0	3422.59
2.	101.5	50.75	11	25.375	180	3422.59
3.	123.5	11.	11.	56.25	180	426.68

$\int_z B_y^{exp} dz$=2453 Gs mm; $\int_z B_y^{sim} dz$=2609 Gs mm; δ= - 6.0%.

2609+25 (result of the linear extrapolyation field tail out of the picture) =2634

2453+25=2478 Gs mm, then δ= - 5.9%

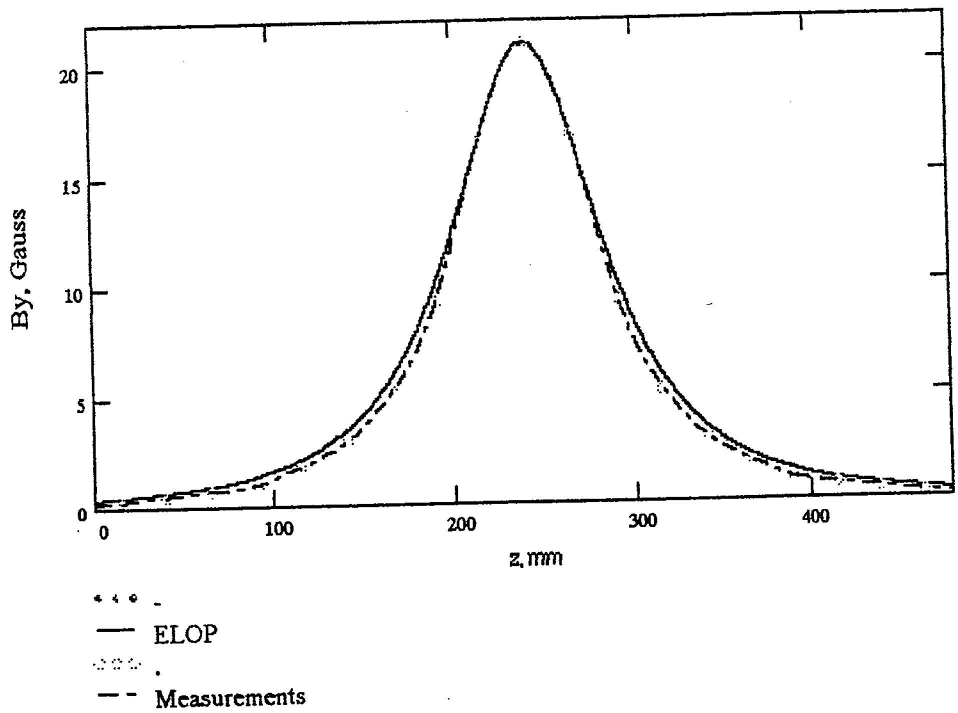

Fig.5. UCLA-type steering coil model after optimization.

This is a satisfactory fit!

2.2. VH5 steering coil

Table 4.

Optimized model parameters of the steering coil VH5

	a	b	c	d	φ, deg	Bs, Gs
1.	207	92.5	11	46.25	0	5872.89
2.	185	92.5	11	46.25	180	5872.89
3.	207	11	11	98	180	1049.49

$\int_z B_y^{exp} dz = 2668$ Gs mm; $\int_z B_y^{sim} dz = 2628$ Gs mm; $\delta = 1.5\%$.

2628+160 (tail) =2788 Gs mm, then $\delta = -4.3\%$

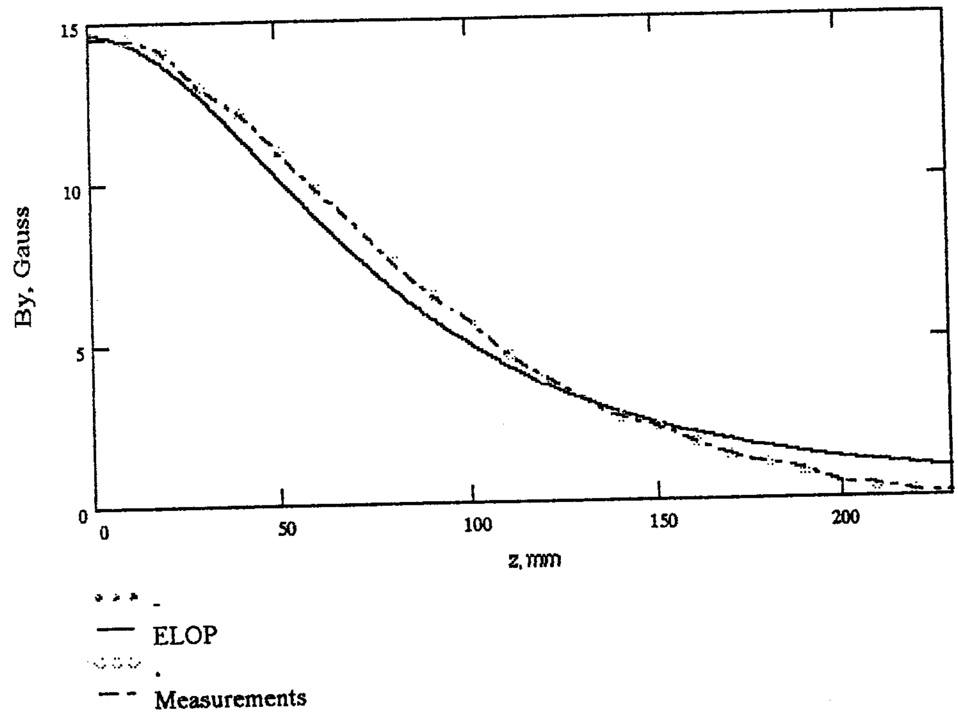

Fig. 6. VH 5 steering field displacement along the beam-axis.

2.3. VH6 steering coils.

Table 5.

Optimized model parameters for the VH6 steering magnet

	a	b	c	d	φ, deg	Bs, Gs
1.	217	96.5	12	48.25	0	3496.75
2.	193	96.5	12	48.25	180	3496.75
3.	217	12	12	102.5	180	461.2

$\int_z B_y^{exp} dz = 1641$ Gs mm; $\int_z B_y^{sim} dz = 1603$ Gs mm; $\delta = 2.3\%$.

1603+71=1674 Gs mm

1641+71=1712 Gs mm, then $\delta = 2.2\%$.

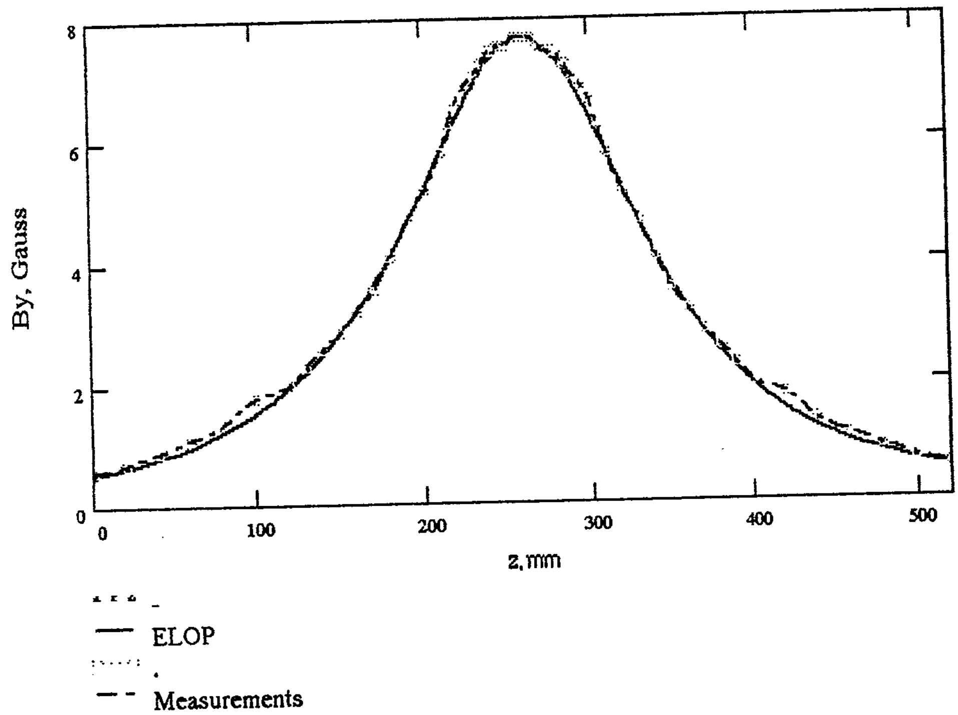

Fig. 7. VH 6 steering coil fild.

3. Conclusion

3.1. Steering coil UCLA -type (VH4, VH7) is equivalent for I=1A to magnets assembly of Table 6.

Table 6.

UCLA - type 1 steering coil parameters after optimization for I=1A.

	a	b	c	d	φ, deg	Bs, Gs
1.	217	96.5	12	48.25	0	2139.12
2.	193	96.5	12	48.25	180	2139.12
3.	217	12	12	102.5	180	266.68

For both cases $\int_z B_y\,dz$=1646 Gs mm /A, that corresponds to full bending angle α=0.0268 rad./A for beam energy 1.4 MeV.

3.2. Steering coil VH5 - type is equivalent for I=1A to magnets assembly of Table 7.

Table 7.

VH5 steering coil parameters after optimization for I=1A.

	a	b	c	d	φ, deg	Bs, Gs
1.	123.5	50.75	11	25.375	0	6054.53
2.	101.5	50.75	11	25.375	180	6054.53
3.	123.5	11.	11.	56.25	180	1081.95

$\int_z B_y\,dz$=2874 Gs mm /A, that corresponds to bending angle α=0.0467rad./A for beam energy 1.4 MeV.

3.3. Steering coil VH6 - type for I=1A (Table 8).

Table 8.

VH6 steering coils parameters after optimization for I=1A

	a	b	c	d	φ, deg	Bs, Gs
1.	217	96.5	12	48.25	0	1748.38
2.	193	96.5	12	48.25	180	1748.38
3.	217	12	12	102.5	180	230.6

$\int_z B_y\,dz$=837 Gs mm /A, that corresponds to bending angle α=0.0136 rad./A for beam energy 1.4 MeV.

3.4. Optimization by first integral.

Table 9

Mechanical parameters

	Position	z, mm * AUTOCAD	z, mm * Wiggler center	z, mm * ELOP (parameter l)	Dimensions (external iron), mm^2	# Windings
VH4	After quads (UCLA)	-870	-860	282.275	123.5× 123.5	256
VH5	Wiggler entrance	-615	-605	27.275	207.0× 207.0	
VH6	Wiggler exit	610	620	53.385	217.0× 217.0	
VH7	Before quads (UCLA)	1005	1015	448.385	123.5× 123.5	256

* z AUTOCAD - coordinate relative to the center of the wiggler center flange.

z wiggler center - coordinate relative to the wiggler center, located a -10mm relative to the AUTOCADE origin.

z ELOP (l) - Before the wiggler: positive distance of location before the center of the first wiggler periodic magnets -577.725mm relative to wiggler center.

After the wiggler: Positive distance of location after the center of the last wiggler periodic magnets - +566.615mm relative to wiggler center.

Table 10.

Electron optical parameters

	$\frac{dB_s(1,2)}{dI}$ Gs/A	$\frac{dB_s(3)}{dI}$ Gs/A	$\frac{d\int_z B_y dz}{dI}$ Gs mm/A	$\frac{d\alpha}{dI}$ mrad/A	Max. current A	α_{max}, mrad
VH4	2084.57	259.88	1604	26.1	~~3.0~~ 3.3	78.3
VH5	5794.19	1035.43	2750.5	44.7	~~1.25~~ 1.5	~~55.88~~
VH6	1788.59	235.9	820.5	13.3	~~3.3*~~ 3.3	~~43.89~~ [illegible]
VH7	2084.57	259.88	1604	26.1	~~3.0~~ 3.3	78.3

Field variation due to displacement in the x - direction was not stadied carefully experimentally. Simulations by ELOP-code in x dimension (perpendicular to the B_y field) show, that the maximum B_y field component in a displacement distance 5mm from the z-axis exceeds the field on the z - axis no more than 1% for steering coils VH4 and VH7 (UCLA - type).

Polarization of the "Addition magnets" (option of the ELOP), which are used for modelling steering coils, allow presently to describe trajectory correction in the x - direction (direction of wigling) only.