Heat properties of an IP chamber
(Or maximum heat dissipation in the IP region)

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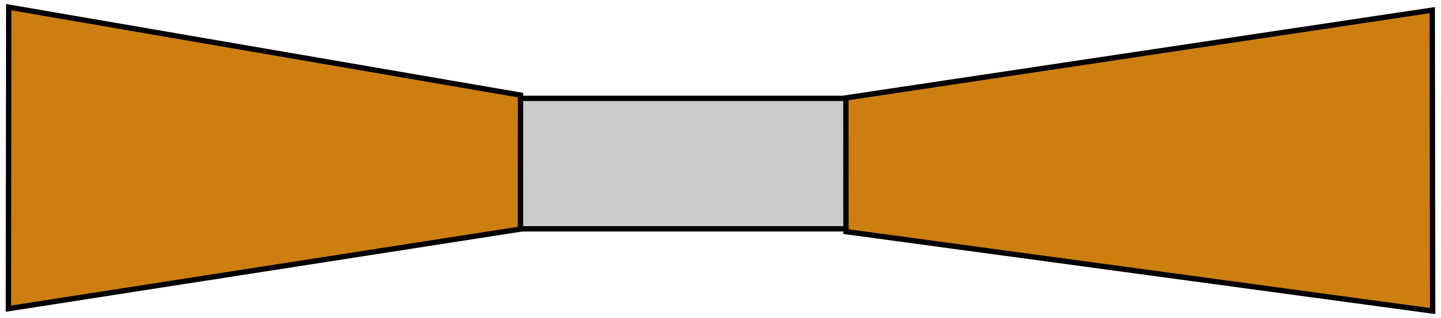
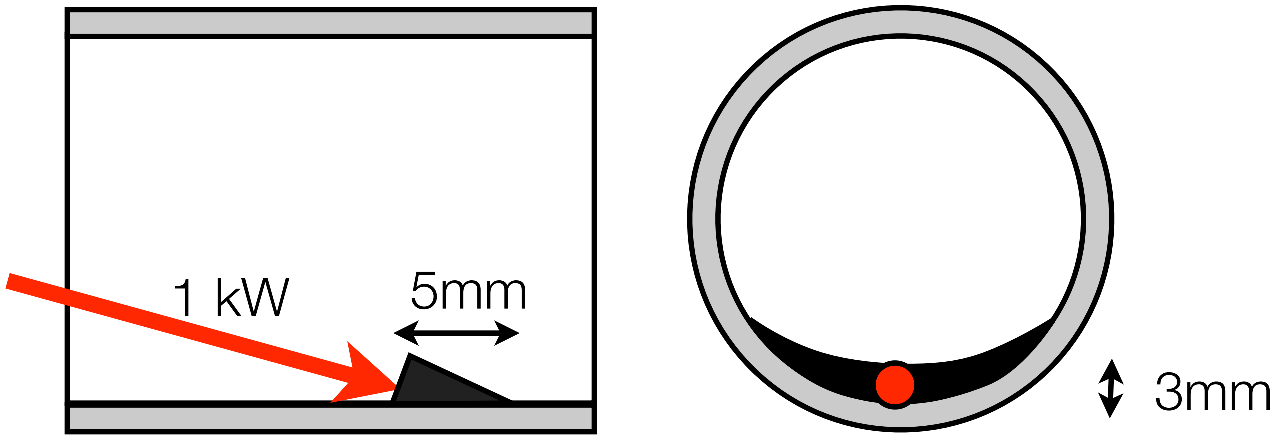
Total heat removed with the IP chamber

- The Belle IP chamber can be cooled as follows.
- For the beryllium part, 1 liter/min water may be the maximum if we keep 1 mm water layer thickness.
- If we allow an increase of the coolant temperature: Δt=5 °C, the heat corresponds to P=5*4.2*1000/60=350 W.
  - If the length of the beryllium part is shortened, we can flow more water and the heat generation would be smaller, too.
- For the support part, the flow rate of 5 liter/min may be possible on either side.
- With Δt=10°C, total power dissipation is P=7 kW.



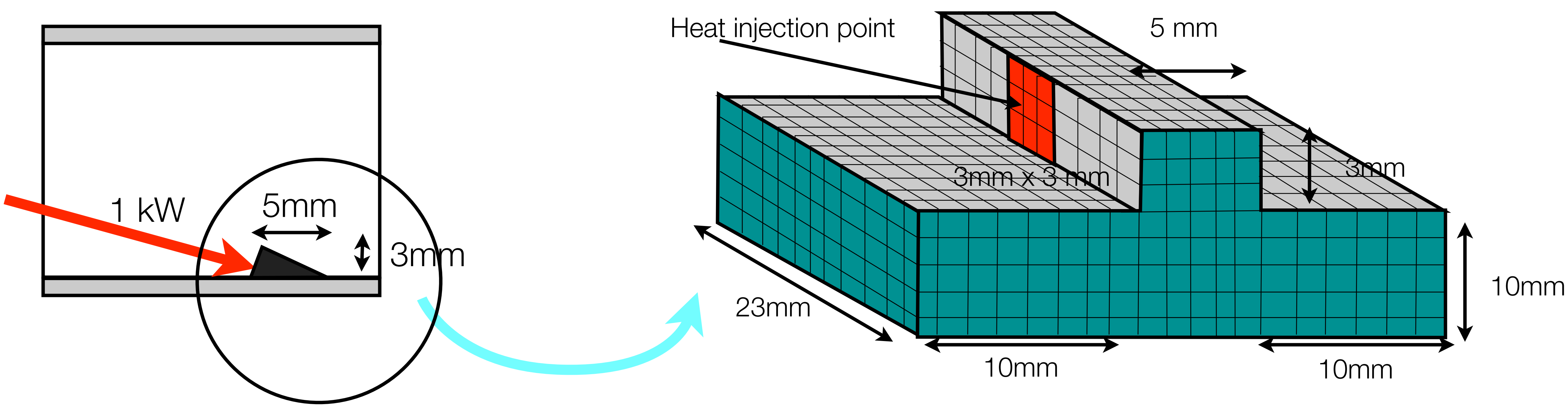
Heat at the synchrotron light mask

- Simplest calculation: 1 Dim. model.
- Temperature increase is $\Delta T = P \cdot L / S / \sigma$, where P: power, L: length, S: area and σ: heat conductivity.
- Assumption: P=1 kW heat lost at the 3 mm diameter spot. $S = \pi r^2 = 0.07$ cm^2. L = 0.3 cm (being half of the maximum length).
- Copper: σ=4.0 W/°C/cm, Tungsten: σ=1.7 J/°C/cm.
- Consequently, ΔT=1000*0.3/0.07/4 ~ 1200 °C for Cu and ΔT= 1000*0.3/0.07/1.7 ~ 2500 °C for W.
- 1 KW power dissipation at a 3 mm diameter heat spot is out of question.



3D calculation

- The heat differential equation is solved by a 3D discrete finite difference method.
- The following model was made and calculated.
- The bottom surfaces are connected to a heat sink (0 °C)
- The other surfaces are heat insulated.
- Calculation was done with equal mesh size: 1 mm in x,y,z direction.



Result

- The temperature distribution Δt for the center slice after equilibration (in one second) is shown below.
- The temperature goes up to Δt=~450 °C.

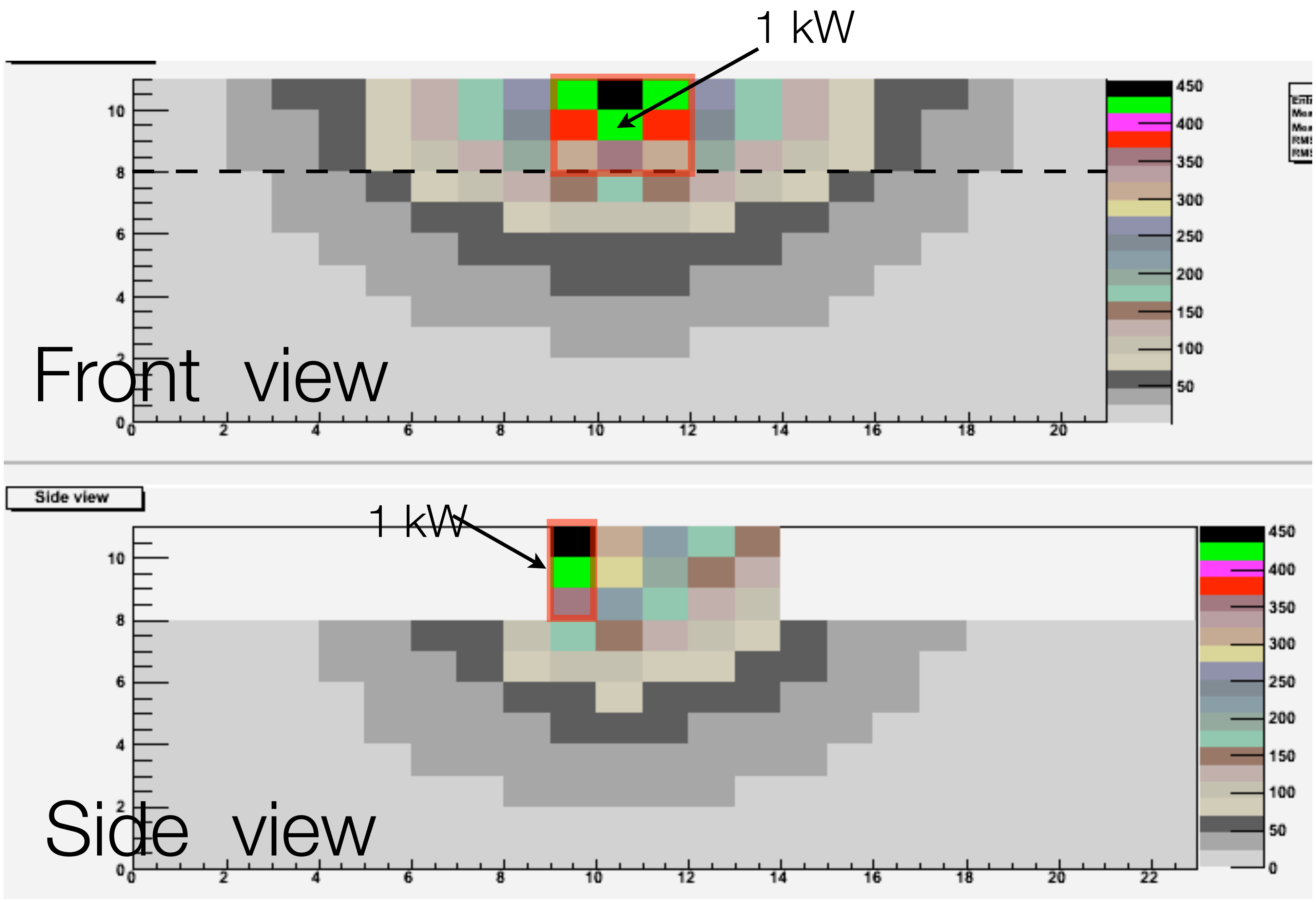
1 kW

10	21	33	48	66	90	124	175	259	413	457	413	259	175	124	90	66	48	33	21	10
10	20	32	45	62	84	115	161	238	384	424	384	238	161	115	84	62	45	32	20	10
9	18	28	40	54	72	97	133	193	312	344	312	193	133	97	72	54	40	28	18	9
7	14	22	31	42	55	71	92	120	155	167	155	120	92	71	55	42	31	22	14	7
6	12	19	26	34	43	55	67	82	95	100	95	82	67	55	43	34	26	19	12	6
5	10	15	21	28	35	42	51	59	65	68	65	59	51	42	35	28	21	15	10	5
4	8	13	17	22	27	33	38	43	47	48	47	43	38	33	27	22	17	13	8	4
3	7	10	14	17	21	25	29	32	34	35	34	32	29	25	21	17	14	10	7	3
3	5	8	11	13	16	19	21	23	25	25	25	23	21	19	16	13	11	8	5	3
2	4	6	8	10	11	13	15	16	17	17	17	16	15	13	11	10	8	6	4	2
1	2	4	5	6	7	9	10	10	11	11	11	10	10	9	7	6	5	4	2	1

1 kW

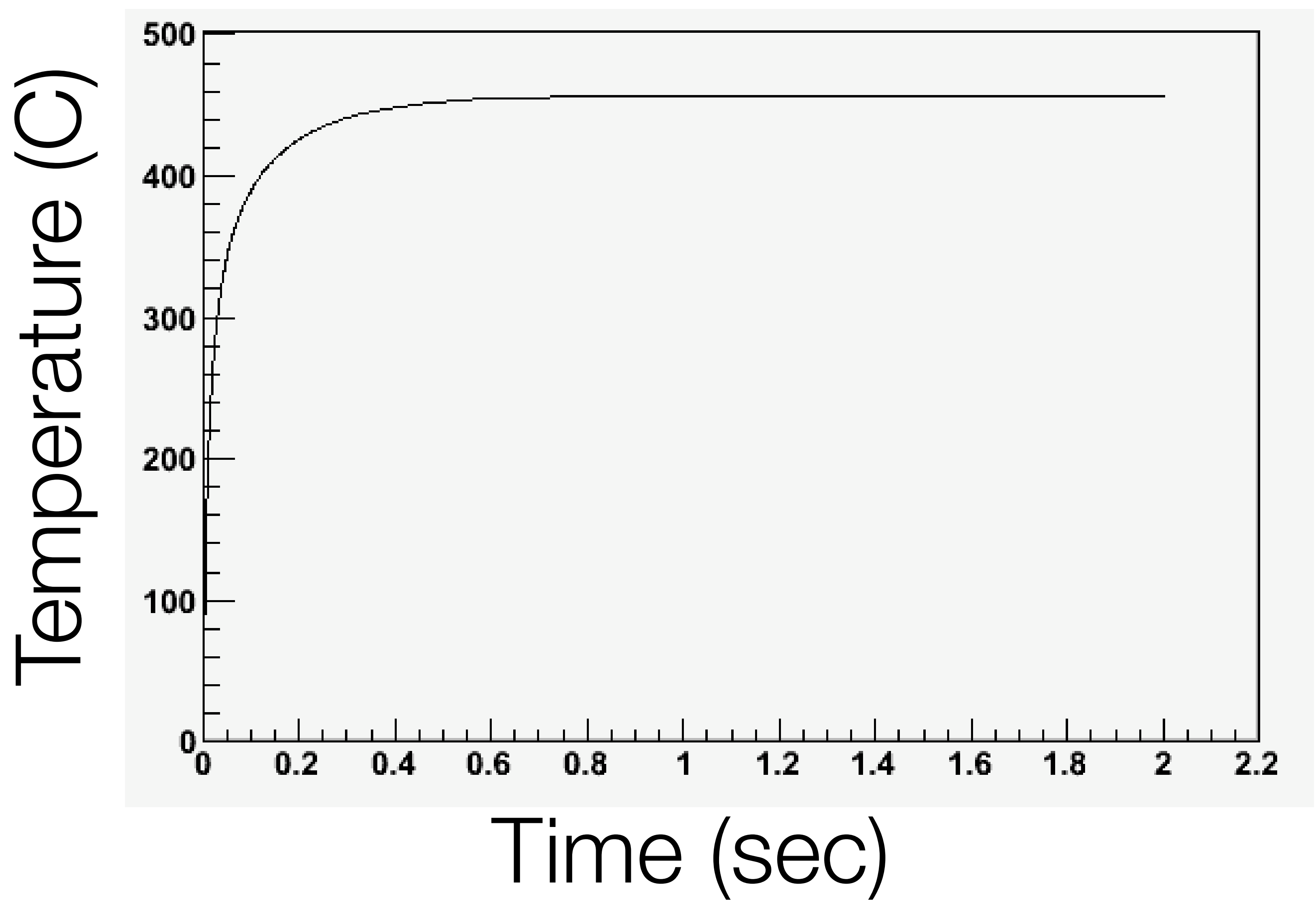
									457	299	212	166	145									
									424	275	196	154	135									
									344	225	164	131	114									
4	8	12	17	24	33	46	66	100	167	150	124	102	83	57	41	30	23	17	12	9	5	3
4	7	11	16	23	31	41	56	77	100	100	90	78	64	49	37	28	21	16	12	8	5	3
3	7	10	15	20	27	35	45	57	68	70	66	59	50	41	32	25	19	15	11	8	5	2
3	6	9	13	17	23	29	36	43	48	50	48	44	39	32	27	21	17	13	10	7	4	2
2	5	8	11	14	18	23	27	32	35	36	35	33	29	25	21	17	14	11	8	6	4	2
2	4	6	9	11	14	17	20	23	25	26	26	24	22	19	16	14	11	9	7	5	3	2
1	3	5	6	8	10	12	14	16	17	18	18	17	15	14	12	10	8	6	5	4	2	1
1	2	3	4	5	7	8	9	10	11	11	11	11	10	9	8	7	5	4	3	2	2	1

Visualize


1 kW
Front view
Side view
1 kW
450
400
350
300
250
200
150
100
50
0

Time evolution

- Highest temperature point
- Within 1 sec. The tip is heat up to 500 degrees.



Summary

- Beryllium chamber
  - 350 W of heat HOM+mirror current can be removed in the beryllium chamber. We need 2 mm thick beryllium + 1 mm water channel in this case
- The support (conical) part
  - Up to 7 kW of heat can be removed.
  - If the heat is large, it must be uniformly distributed.
  - If the heat is concentrated to a particular position the temperature raise might be dangerous.
  - We need reliable corrosion protection as the flow will be completely turbulent.
- Synchrotron Light mask
  - The temperature goes up to Δt=~500 °C with 1 kW heat in a 3mm x 3 mm spot.
  - The heat dissipation to the mask should be of order 100 W.
  - Cooling by radiation is not included, however, it may help the cooling at such high temperature.
  - Next step: reliable calculation by ANSYS or a similar tool.

Appendix

Material	Density (g/cm^3)	Heat Cap. (J/K/g)	Heat Cap. (II) ($J/K/cm^3$)	Heat cond. (W/K/cm)
H_2O	1	4.2	4.2	
C_nH_{2n+2}	0.75	1.6	1.2	
Cu	9.0	0.38	3.4	4.0
Ag	10.5	0.23	2.4	4.2
Ta	16.6	0.15	2.5	0.57
W	19.3	0.13	2.5	1.7