Preliminary Layout of LIGO-2 Power & Signal Recycling Cavities

(to determine laser beam elevation and SEI optics table elevations)

Kip & Eanna's beam tube baffle backscatter and diffraction analysis (T950132 for 1064 nm light, no account taken of beam waist size) limit the minimum distance of the laser beam center to the edge of the baffles to 200 mm for a 2x increase in the backscatter phase noise. If 40 kg sapphire masses are used, then the diameter ~ 314 mm and with allowance for suspension structure, the lateral separation of two interferometer beams whousl be about 200 mm (same as LIGO-1). At +/- 200 mm lateral separation, the backscatter limit of vertical position in the LIGO global coordinate system is z = +/- 275 mm.

The apparent lower limit of the HAM optics table is z = –315 mm (maximum compression of the 'stiff' design without serious design consideration).
SEI group: Similar limit on the elevation range for the BSC optics table??

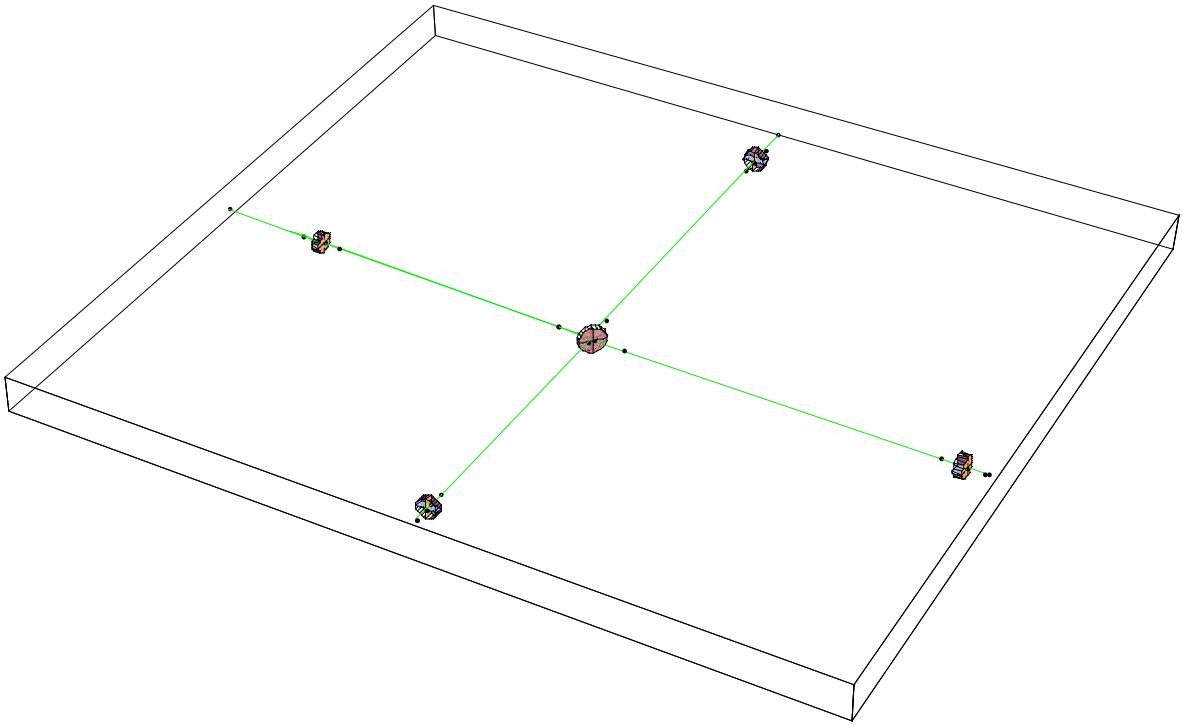
The recycling cavity layout must attempt to stay within these bounds while selecting wedge angles sufficient to separate optical signals and ghost beams for dumping. A preliminary layout with 4 cases has been made. See sketch for nomenclature.

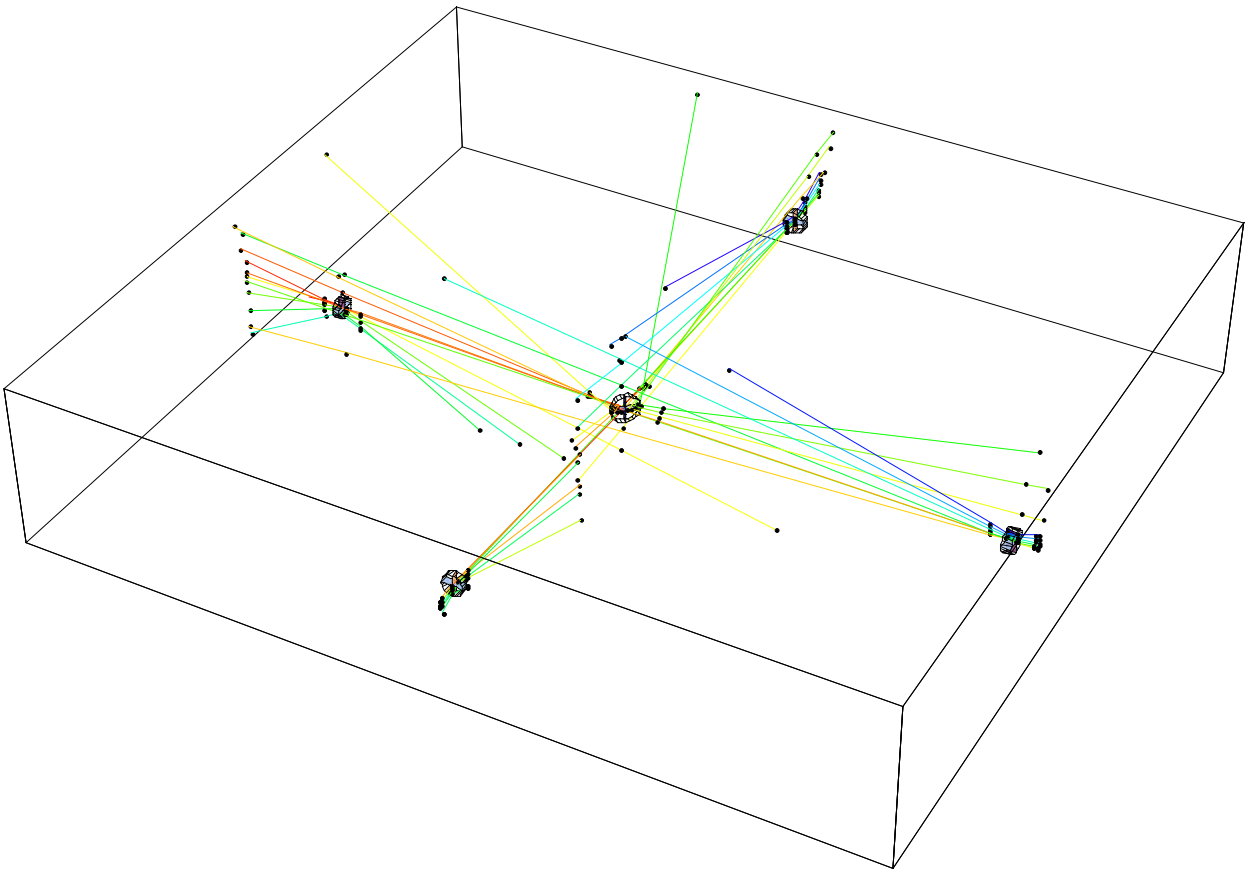
Assuming PRM and SRM diameter = 254 mm and 25 mm clearance from lower edge of optic and the optic table, then the minimum laser beam height at the SRM and PRM is –315+254/2+25 = -163 mm

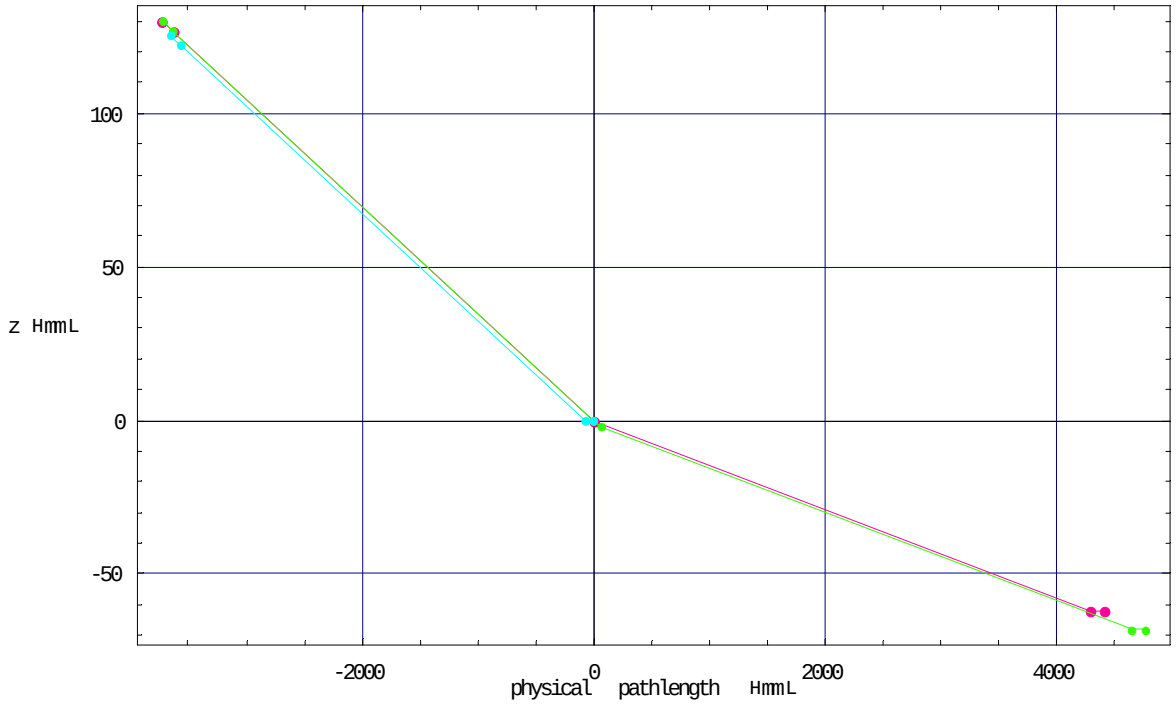
[all dimensions in mm]

		Beam height (Zglobal, mm)			Optics Table Elevation			
	Case	@SRM, PRM	@BS	@ITMs	@HAM	@BSC	Wx[940mm]	Notes
1	Vertical Wedges: ITM & BS with thick sides up (like LIGO-1)	-75	-205	-275	-227	?	393	at BT baffle diffraction placement limit
2	Vertical Wedges: ITM with thick side up, BS with thick side down	-163	-143	-213	-315	?	915	1st PRM ghost beam hits BS - - PRM wedge is too small (~0.5 deg)
3	Vertical Wedges: ITM & BS with thick sides down	-163	-33	37	-315	?	915	-harder to suspend with thick side down? -BSC table too high?
4	Horizontal Wedges	-163	-163	-163	-315	?	915	- requires PO mirrors & beam dumps on long structures (low freq. Structures) - Not yet clear that we ave all the real-estate to take this approach

1. **Case 1: Vertical Wedges, ITM & BS with thick sides up, PRM & SRM with thick sides down (similar to LIGO-1)**







Wedges angles used:

optic	wedge HradL	wedge HdegL
wedgePRM	0.0461542	2.64444
wedgeSRM	0.0462129	2.64781
wedgeBS	0.0226893	1.3
wedgeITM	0.0191986	1.1

Resulting coordinates of cardinal points (chief ray intercept on BS 50/50 surface defined as the origin):

point	X	Y	Z
p2	-3722.87	-1.87394	129.936
p3	-3628.79	-1.82659	126.652
p4	0	0	0
p5	65.1384	-25.3013	-1.90631
p5p	25.3213	-65.1584	0.0607351
p6	4638.76	-25.3013	-68.19
p7	4754.02	-25.3013	-68.19
p8	0.	4296.31	-62.2646
p9	0.	4411.57	-62.2646
p10	23.5539	-3561.37	122.242
p11	23.5064	-3655.44	125.529

Surface normal vectors:

point	X	Y	Z
n2	-0.996718	-0.000501708	0.0809534
n3	-0.999391	-0.000503053	0.0348808
n4	-0.707033	0.707033	0.014425
n5	-0.70662	0.70662	0.0371063
n6	-0.999816	-1.1284×10^{-20}	-0.0191974
n7	-1	0	0
n8	0.	-0.999816	-0.0191974
n9	0	-1	0
n10	0.000505202	0.99939	-0.0349253
n11	0.000503853	0.996709	-0.0810563

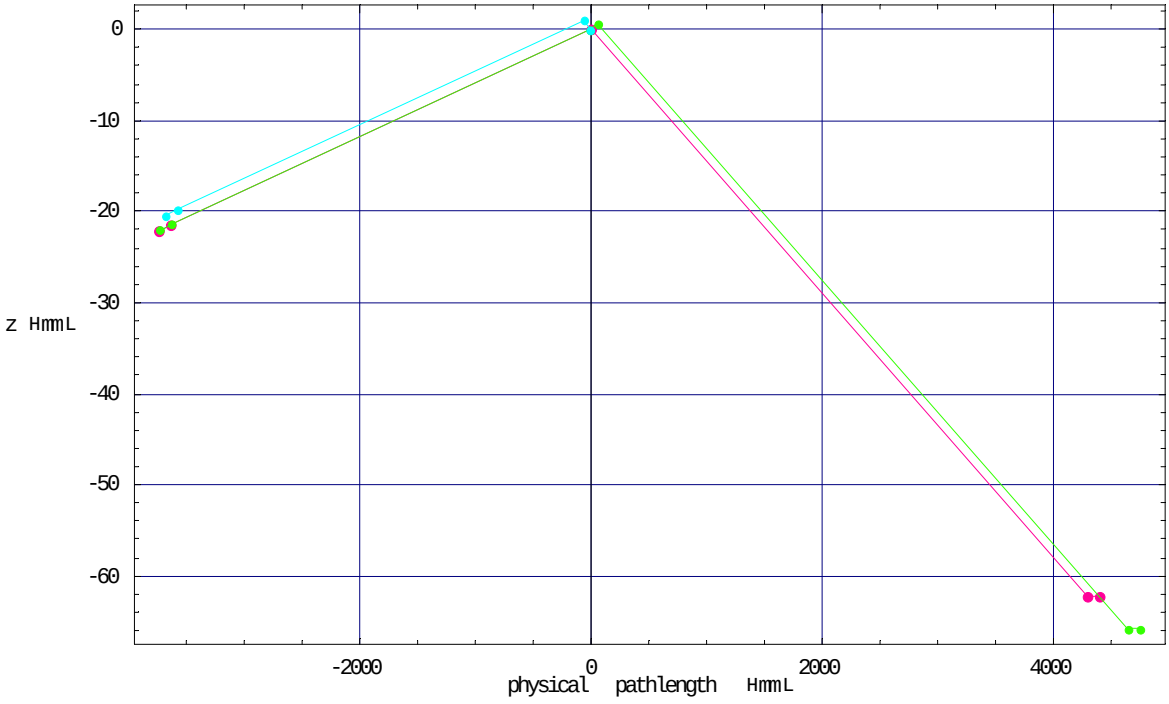
Cardinal unit ray vectors:

point	X	Y	Z
u2	1.	0.00050336	4.32057×10^{-13}
u3	0.999391	0.000503053	-0.0348808
u4	0.999391	0.000503053	-0.0348808
u5	0.931805	-0.361935	-0.0272697
w4p	0.362221	-0.932092	0.000868815
u6	0.999895	-8.51766×10^{-21}	-0.0144911
u7	1	0	0
u8	0.	0.999895	-0.0144911
u9	0	1	0
u10	-0.000505202	-0.99939	0.0349253
u11	-0.000505202	-0.99939	0.0349253

2. Case 2: Vertical Wedges, ITM, PRM & SRM with thick sides up, BS with thick side down

Wedges angles:

optic	wedge [rad]	wedge [deg]
wedgePRM	0.00783251	0.44877
wedgeSRM	-0.00782734	-0.448474
wedgeBS	-0.0226893	-1.3
wedgeITM	0.0191986	1.1



point	X	Y	Z
p2	-3729.94	0.307597	-22.0468
p3	-3630.94	0.299433	-21.4616
p4	0	0	0
p5	57.0593	-22.172	0.658526
p5p	22.1692	-57.0561	0.957902
p6	4645.92	-22.172	-65.846
p7	4761.18	-22.172	-65.846
p8	0.	4296.31	-62.2646
p9	0.	4411.57	-62.2646
p10	22.4768	-3570.58	-19.796
p11	22.4857	-3671.57	-20.3926

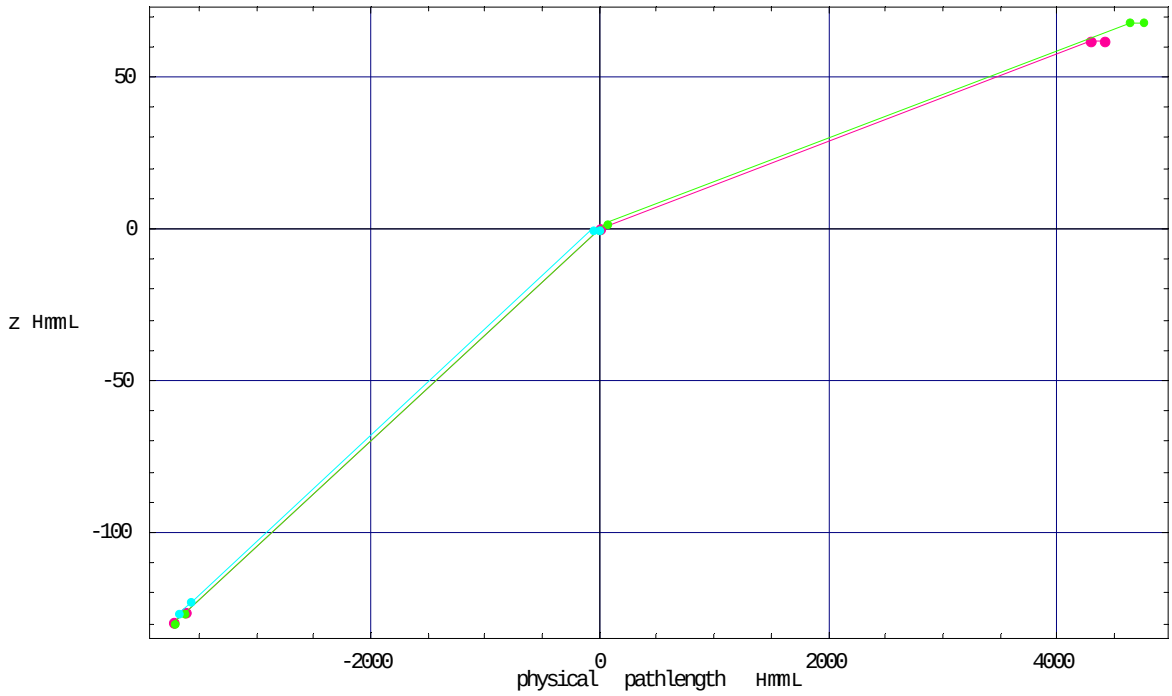
point	X	Y	Z
n2	-0.999906	0.0000824592	-0.0137428
n3	-0.999983	0.0000824656	-0.00591067
n4	-0.707035	0.707031	-0.014425
n5	-0.706622	0.706618	-0.0371063
n6	-0.999816	-1.1284×10^{-20}	-0.0191974
n7	-1	0	0
n8	0.	-0.999816	-0.0191974
n9	0	-1	0
n10	-0.0000875527	0.999983	0.00590677
n11	-0.0000875463	0.999906	0.0137337

point	X	Y	Z
u2	1.	-0.000082467	-5.46356×10^{-13}
u3	0.999983	-0.0000824656	0.00591067
u4	0.999983	-0.0000824656	0.00591067
u5	0.932049	-0.362173	0.0107568
w4p	0.362128	-0.931997	0.0156471
u6	0.999895	-8.51766×10^{-21}	-0.0144911
u7	1	0	0
u8	0.	0.999895	-0.0144911
u9	0	1	0
u10	0.0000875527	-0.999983	-0.00590677
u11	0.0000875527	-0.999983	-0.00590677

3. Case 3: Vertical Wedges, ITMs and BS with thick sides down, SRM and PRM with thick sides up

Wedges angles:

optic	wedge [rad]	wedge [deg]
wedgePRM	0.0461545	2.64446
wedgeSRM	-0.0462131	-2.64782
wedgeBS	-0.0226893	-1.3
wedgeITM	-0.0191986	-1.1



point	X	Y	Z
p2	-3722.87	-1.89501	-129.936
p3	-3628.79	-1.84712	-126.652
p4	0	0	0
p5	57.051	-22.1597	1.66962
p5p	22.1775	-57.0684	-0.0531937
p6	4636.3	-22.1597	68.0348
p7	4757.04	-22.1597	68.0348
p8	0.	4286.71	62.1255
p9	0.	4407.44	62.1255
p10	20.4024	-3568.5	-122.766
p11	20.349	-3674.31	-126.464

point	X	Y	Z
n2	-0.996718	-0.000507347	-0.0809536
n3	-0.999391	-0.000508708	-0.0348808
n4	-0.707035	0.707031	-0.014425
n5	-0.706622	0.706618	-0.0371063
n6	-0.999816	-1.1284×10^{-20}	0.0191974
n7	-1	0	0
n8	0.	-0.999816	0.0191974
n9	0	-1	0
n10	0.000505206	0.99939	0.0349254
n11	0.000503841	0.996709	0.0810566

point	X	Y	Z
u2	1.	0.000509018	-2.51669×10^{-7}
u3	0.999391	0.000508708	0.0348808
u4	0.999391	0.000508708	0.0348808
u5	0.931806	-0.361931	0.0272697
w4p	0.362222	-0.932091	-0.000868806
u6	0.999895	-8.51766×10^{-21}	0.0144911
u7	1	0	0
u8	0.	0.999895	0.0144911
u9	0	1	0
u10	-0.000505206	-0.99939	-0.0349254
u11	-0.000505206	-0.99939	-0.0349254

4. Case 4: Horizontal Wedges

Wedge angles:

optic	wedge HradL	wedge HdegL
wedgePRM	-0.0578878	-3.31672
wedgeSRM	-0.0169644	-0.971987
wedgeBS	0.0226893	1.3
wedgeITM	0.0191986	1.1

point	X	Y	Z
p2	-3734.77	163.69	0.
p3	-3627.52	158.989	0.
p4	0	0	0
p5	64.0283	-27.543	0.
p5p	23.766	-65.5241	0.
p6	4638.01	-93.8318	0.
p7	4753.27	-93.8318	0.
p8	62.2646	4296.31	0.
p9	62.2646	4411.57	0.
p10	68.5631	-3563.94	0.
p11	69.8711	-3666.09	0.

point	X	Y	Z
n2	-0.994834	0.101513	0.
n3	-0.999041	0.0437865	0.
n4	-0.6862	0.727413	0
n5	-0.66952	0.742794	0.
n6	-0.999816	-0.0191974	0.
n7	-1	0	0
n8	0.0191974	-0.999816	0.
n9	0	-1	0
n10	-0.0128039	0.999918	0.
n11	-0.0297643	0.999557	0.

point	X	Y	Z
u2	1.	2.1699×10^{-12}	0.
u3	0.999041	-0.0437865	0.
u4	0.999041	-0.0437865	0.
u5	0.918613	-0.395159	0.
w4p	0.34097	-0.940074	0.
u6	0.999895	-0.0144911	0.
u7	1	0	0
u8	0.0144911	0.999895	0.
u9	0	1	0
u10	0.0128039	-0.999918	0.
u11	0.0128039	-0.999918	0.

Figure (7) Ray Vector Notation for the LIGO Recycling Cavity (4km IFO)