PANGOLIN LASER SYSTEMS

SafetyScan Lens

User Manual

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Introduction

Audience scanning is the most beautiful thing you can do with a laser. Indeed, it's what separates lasers from any other lighting effect or medium, because with Audience Scanning, you can involve your audience in a very intimate way. The light literally reaches out and touches the audience. However, there are a few problems to overcome. When you do audience scanning the typical way, using the raw laser beam, the beam is so small that the entire beam's power can go into the viewer's eye. Where safety regulations are strictly enforced, such as the US, UK and Australia, the maximum amount of un-diverged laser power you can use while complying with the MPE is only 10 milliwatts. Obviously this does not make a very effective show. Outside these countries and where safety regulations are more relaxed or not enforced, often times higher laser power is used. However, with high power lasers, audience scanning effects can be unpleasant as they sweep past your eye. This is because, again, the beam is so small that the entire beam's power scans across the pupil of the eye.

The solution is to use Pangolin's SafetyScan lenses. They increase the divergence of the laser, but only within the audience area. Because the beam is bigger, less laser light gets shone directly into the pupils of the audience. Due to the inverse-square law that governs light, this means that higher actual laser power can be used, because since the beam is bigger, not all of it will fit into the pupil of the viewer's eye. The result is that higher laser power can be used, and the show is much more effective. The side benefit is that since the beam is bigger, it also makes a much more pleasant, softer audience scanning experience, but only in the audience area. Above the heads of the audience, the laser beam is unchanged, so the "marbling" effect seen in fog remains, and the spectacle, brilliance and drama of an audience scanning laser show is retained.

The SafetyScan lens can easily be attached directly to the front of any laser projector. Aside from mounting the lens, generally no other changes are needed. And due to the simple "binary" nature of the SafetyScan lens (the laser beam is either affected or it isn’t), the SafetyScan lens is a simple and reliable solution.

Once the proper SafetyScan lens is installed on a projector, the result is a powerful show, that is much safer for those in attendance, and much more pleasant to watch.

In addition to the information provided below, Pangolin has also produced a 40-minute video showing exactly how to mount the lens, how to perform safety measurements, and the resulting laser shows. Please contact Pangolin if you did not receive the video along with this manual.

Lens selection
(how the lens affects the beam divergence and spot size)

The effective divergence, and thus, the spot size caused by the SafetyScan lens, depends on the beam divergence, and the beam quality parameter (M^2) of the laser beam. The better the beam quality (lower values of M^2), the less effect the SafetyScan lens has on the laser beam divergence. For a detailed explanation of M^2, see the Wikipedia article here: http://en.wikipedia.org/wiki/M_squared

Using the tables

Below you will see tables that show the spot size at distances ranging from 5 meters to 35 meters from the projector, for laser beams whose full-angle divergence is 1.0 mRad, 2.0 mRad and 3.0 mRad, having beam quality parameter (M^2) of 1.2, 3.0 and 5.0. The “Divergence” column on the right shows the approximate effective divergence with a lens in place.

Note that the beam divergence and M^2 of the laser beam work together in nonlinear ways, and thus the values in the tables may seem unintuitive. Also note that the tables were calculated for a green wavelength, and that the lens has a greater effect for red wavelengths and lesser effect for blue wavelengths.

The tables should serve as a starting point for lens selection, and not as a definitive final answer. Many laser manufacturers do not state their beam quality parameter (M^2) and thus, this may not be easy to obtain. Moreover, for poor- quality lasers, the M^2 may change over time, or the beam may be distorted by other projector optics.

It is recommended that you observe the spot size on the exit aperture window of the laser projector and compare this with the “Spot size at the exit aperture” stated below within the tables. Then look at the spot size at your target distance and compare this with the spot size shown in the table for no lens. These two will help to give you a “sanity check” of your divergence and probable M^2 of your laser. Then choose a lens that provides the desired spot size.

Note that Pangolin highly suggests that, once the lens selection is made and the lens is in place, you measure the laser beam irradiance using an energy meter, to confirm that it is safe for audience scanning.

Lasers with M^2 of 1.2

When the beam quality (M^2) is close to 1.0, it represents a near perfect, Gaussian beam. Lasers with this kind of beam quality include lasers that use gases including Argon, Krypton, Helium-Neon, etc. Coherent Optically-Pumped Semiconductor Lasers also have very good beam quality with low M^2. Some low power, high quality DPSS lasers may also have M^2 of around 1.2.

Laser beam with 1.0 milliradian full-angle divergence and M^2 of 1.2
(Spot size at the exit aperture of the projector = 0.83 mm)

	5 meters	10 meters	15 meters	20 meters	25 meters	30 meters	35 meters	Divergence
No lens	5.31	10.28	15.27	20.27	25.26	30.26	35.26	1.0
1 diopter	8.04	15.43	22.82	30.21	37.61	45.00	52.39	1.5
2 diopter	11.64	22.53	33.42	44.32	55.21	66.10	76.99	2.2
3 diopter	15.52	30.24	44.97	59.70	74.43	89.16	103.89	3.0
4 diopter	19.50	38.20	56.89	75.59	94.28	112.98	131.68	3.8
5 diopter	23.54	46.26	68.99	91.72	114.44	137.17	159.90	4.6
6 diopter	27.61	54.40	81.19	107.98	134.77	161.56	188.35	5.4

Laser beam with 2.0 milliradian full-angle divergence and M^2 of 1.2
(Spot size at the exit aperture of the projector = 0.64 mm)

	5 meters	10 meters	15 meters	20 meters	25 meters	30 meters	35 meters	Divergence
No lens	10.51	20.51	30.50	40.50	50.51	60.51	70.51	2.0
1 diopter	13.22	25.87	38.52	51.18	63.84	76.49	89.15	2.6
2 diopter	16.10	31.61	47.12	62.63	78.15	93.66	109.17	3.1
3 diopter	19.08	37.55	56.03	74.51	92.98	111.46	129.94	3.7
4 diopter	22.12	43.62	65.12	86.63	108.13	129.64	151.14	4.3
5 diopter	25.19	49.76	74.33	98.91	123.48	148.05	172.62	4.9
6 diopter	28.29	55.96	83.62	111.29	138.96	166.62	194.29	5.6

Laser beam with 3.0 milliradian full-angle divergence and M^2 of 1.2
(Spot size at the exit aperture of the projector = 0.79 mm)

	5 meters	10 meters	15 meters	20 meters	25 meters	30 meters	35 meters	Divergence
No lens	15.75	30.75	45.75	60.75	75.76	90.76	105.76	3.0
1 diopter	19.57	38.36	57.16	75.96	94.75	113.55	132.35	3.8
2 diopter	23.43	46.09	68.74	91.40	114.05	136.71	159.36	4.6
3 diopter	27.33	53.88	80.42	106.97	133.52	160.06	186.61	5.3
4 diopter	31.25	61.71	92.17	122.63	153.09	183.55	214.01	6.1
5 diopter	35.17	69.56	103.95	138.34	172.73	207.11	241.50	6.8
6 diopter	39.11	77.44	115.76	154.09	192.41	230.74	269.06	7.7

Lasers with M^2 of 3.0

Lasers with M^2 around 3.0 may include direct diode lasers. Note that diode lasers usually have divergences that differ between the horizontal and vertical axis, and thus the SafetyScan lens may have a drastically different effect in the shape of the laser once in place. As with the rest of the information in this manual, these tables should be used as a starting point and not as the definitive final answer.

Laser beam with 1.0 milliradian full-angle divergence and M^2 of 3
(Spot size at the exit aperture of the projector = 1.99 mm)

	5 meters	10 meters	15 meters	20 meters	25 meters	30 meters	35 meters	Divergence
No lens	5.61	10.44	15.38	20.35	25.33	30.32	35.31	1.00
1 diopter	13.51	25.19	36.87	48.55	60.24	71.92	83.60	2.40
2 diopter	23.06	44.18	65.31	86.43	107.55	128.67	149.80	4.30
3 diopter	32.85	63.74	94.62	125.51	156.39	187.28	218.16	6.30
4 diopter	42.72	83.46	124.19	164.93	205.67	246.41	287.15	8.20
5 diopter	52.61	103.25	153.88	204.51	255.14	305.77	356.41	10.20
6 diopter	62.53	123.07	183.62	244.16	304.70	365.25	425.79	12.20

Laser beam with 2.0 milliradian full-angle divergence and M^2 of 3
(Spot size at the exit aperture of the projector = 1.11 mm)

	5 meters	10 meters	15 meters	20 meters	25 meters	30 meters	35 meters	Divergence
No lens	10.55	20.53	30.52	40.52	50.51	60.51	70.51	2.0
1 diopter	14.29	27.72	41.16	54.59	68.03	81.47	94.91	2.7
2 diopter	18.93	36.88	54.84	72.80	90.76	108.71	126.67	3.6
3 diopter	23.95	46.87	69.80	92.73	115.65	138.58	161.51	4.6
4 diopter	29.16	57.26	85.37	113.48	141.58	169.69	197.8	5.7
5 diopter	34.47	67.87	101.27	134.67	168.07	201.47	234.87	6.7
6 diopter	39.84	78.60	117.36	156.12	194.88	233.64	272.40	7.8

Laser beam with 3.0 milliradian full-angle divergence and M^2 of 3
(Spot size at the exit aperture of the projector = 1.00 mm)

	5 meters	10 meters	15 meters	20 meters	25 meters	30 meters	35 meters	Divergence
No lens	15.76	30.76	45.76	60.76	75.76	90.76	105.76	3.0
1 diopter	19.90	38.93	57.97	77.01	96.04	115.08	134.12	3.8
2 diopter	24.35	47.80	71.24	94.68	118.13	141.57	165.02	4.7
3 diopter	28.98	57.03	85.08	113.12	141.17	169.22	197.26	5.6
4 diopter	33.72	66.48	99.24	132.00	164.77	197.53	230.29	6.6
5 diopter	38.51	76.06	113.61	151.16	188.71	226.26	263.81	7.5
6 diopter	43.35	85.74	128.12	170.50	212.89	255.27	297.65	8.5

Lasers with M^2 of 5.0

Lasers with M^2 around 5.0 may include DPSS lasers and perhaps direct diode lasers using multiple lasers overlaid into a single beam. As with the rest of the information in this manual, these tables should be used as a starting point and not as the definitive final answer.

Laser beam with 1.0 milliradian full-angle divergence and M^2 of 5
(Spot size at the exit aperture of the projector = 3.30 mm)

	5 meters	10 meters	15 meters	20 meters	25 meters	30 meters	35 meters	Divergence
No lens	6.20	10.77	15.60	20.52	25.47	30.43	35.41	1.0
1 diopter	20.79	38.38	55.98	73.58	91.18	108.78	126.39	3.6
2 diopter	37.02	70.78	104.53	138.28	172.04	205.79	239.55	6.9
3 diopter	53.42	103.56	153.69	203.83	253.96	304.10	354.23	10.1
4 diopter	69.87	136.45	203.02	269.60	336.18	402.75	469.33	13.4
5 diopter	86.34	169.38	252.42	335.47	418.51	501.55	584.59	16.7
6 diopter	102.82	202.34	301.86	401.38	500.90	600.42	699.94	20.0

Laser beam with 2.0 milliradian full-angle divergence and M^2 of 5
(Spot size at the exit aperture of the projector = 1.72 mm)

	5 meters	10 meters	15 meters	20 meters	25 meters	30 meters	35 meters	Divergence
No lens	10.63	20.57	30.55	40.54	50.53	60.53	70.52	2.0
1 diopter	16.33	31.27	46.23	61.19	76.16	91.12	106.09	3.0
2 diopter	23.83	46.09	68.36	90.62	112.89	135.16	157.42	4.5
3 diopter	31.89	62.15	92.41	122.67	152.92	183.18	213.44	6.0
4 diopter	40.18	78.69	117.20	155.71	194.23	232.74	271.25	7.8
5 diopter	48.58	95.56	142.36	189.25	236.14	283.03	329.92	9.5
6 diopter	57.03	112.37	167.70	223.04	278.38	333.71	389.05	11.0

Laser beam with 3.0 milliradian full-angle divergence and M^2 of 5
(Spot size at the exit aperture of the projector = 1.33 mm)

	5 meters	10 meters	15 meters	20 meters	25 meters	30 meters	35 meters	Divergence
No lens	15.79	30.77	45.76	60.76	75.76	90.76	105.76	3.0
1 diopter	20.58	40.11	59.64	79.18	98.71	118.25	137.78	3.9
2 diopter	26.20	51.22	76.26	101.29	126.32	151.35	176.38	5.0
3 diopter	32.20	63.18	94.17	125.15	156.13	187.11	218.09	6.2
4 diopter	38.42	75.59	112.76	149.93	187.09	224.26	261.43	7.5
5 diopter	44.77	88.25	131.74	175.23	218.72	262.21	305.70	8.7
6 diopter	51.18	101.08	150.97	200.87	250.76	300.66	350.55	10.0

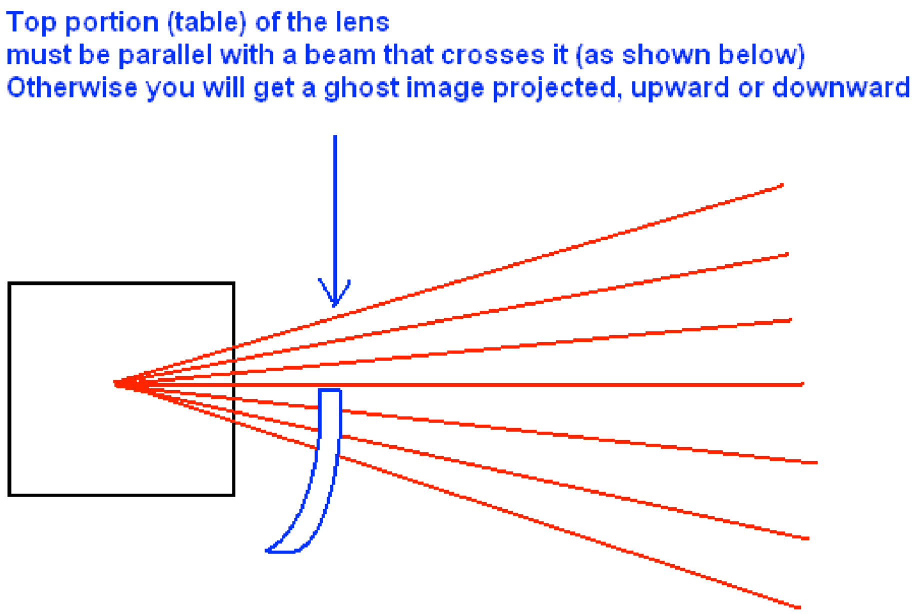
Installing the lens on a projector

The SafetyScan lens is mounted directly to the front of a laser projector. Ideally a lens mount should be used which provides three degrees of adjustment. Each degrees of adjustment is described below:

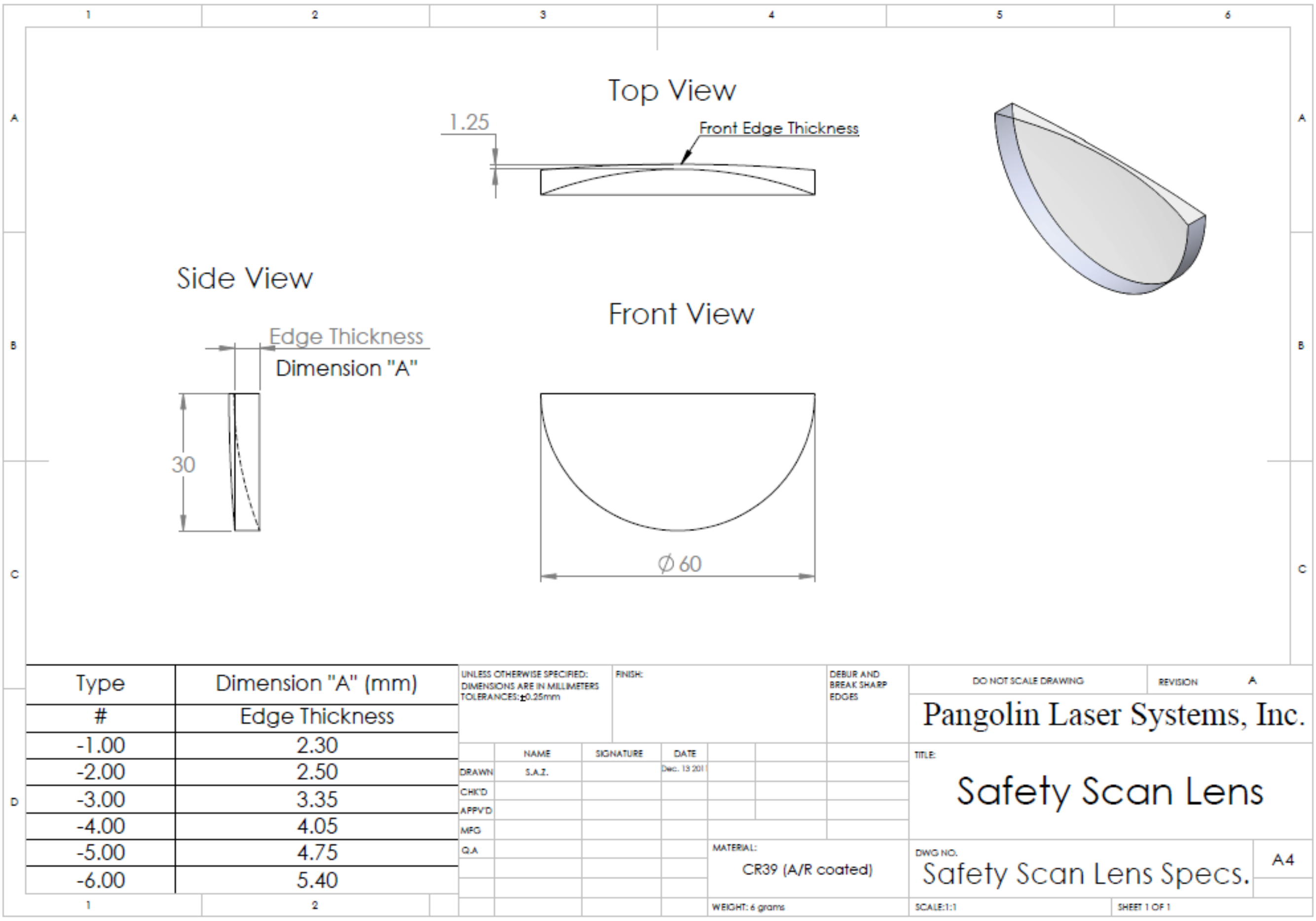
The first degree of adjustment is obvious – up/down. You adjust the lens upward and downward until the beam is diverged primarily in the audience area, but where the beam is not diverged above the heads of the audience members.

The second degree of adjustment is left-right. You will notice that that, in addition to affecting the beam divergence, the lens will also effectively steer the beam leftward or rightward if the center of the lens is not placed precisely over the center of the X-Y scanners. For best results, project a test pattern that has a vertical center line, such as the Pangolin Orientation test pattern. Move the lens leftward and rightward so that the center line of the test pattern is not affected (remains vertical and centered throughout the projected image).

The third degree of adjustment is tilting the lens about the split at the top. If the top portion of the lens is at an angle with respect to the light coming from the X-Y scanners, there will be a kind of "ghost image", which is a reflection off of the top surface of the lens. The lens angle should be adjusted so that the beams for the center of the projection are directly in angular alignment with respect to the top surface of the lens. Doing so will prevent the "ghost image" and the result will be perfect. The crude picture below shows the concept.



Engineering Drawing



Type	Dimension "A" (mm)
#	Edge Thickness
-1.00	2.30
-2.00	2.50
-3.00	3.35
-4.00	4.05
-5.00	4.75
-6.00	5.40

Due to our policy of continuous product improvement, information in this manual is subject to change without notice.

Intellectual Property Notice

There are currently two pending patents on SafetyScan lenses.