SafetyScan Lens and Kvant lens mount

Introduction and purpose for using a lens

Audience scanning is one of the most beautiful things you can do with a laser. Indeed, it's what separates lasers from any other lighting effect or medium, because with Audience Scanning, the light literally reaches out and touches the audience. However, there are a few potential hazards to overcome. When audience scanning shows are performed the typical way (using the raw laser beam) that beam is typically so small that the entire beam's power can enter a show-viewer's eye. Where safety regulations are strictly enforced, such as the US, UK and Australia, studies have shown that the maximum amount of un-diverged laser power you can use while complying with the MPE is only around 10 milliwatts. Obviously, such a low laser power would not make a very effective show. Outside of these countries, and where safety regulations are more relaxed or not enforced as vigorously, often times higher laser power is used. Nevertheless, aside from safety concerns, when high power lasers are used, audience scanning effects can be unpleasant as they sweep past a viewer’s eye. This is because, again, the beam is so small that the entire beam's power scans across the pupil of the eye.

One easy solution is to use Pangolin's SafetyScan lenses. They increase the divergence of the laser, but only within the audience area. Once affected by Pangolin’s SafetyScan lenses, the beam becomes bigger, and because the beam is bigger, this effectively lowers the irradiance (beam power per unit area) that enters the pupils of the audience members. Due to the inverse-square law that governs light, this means that higher actual laser power can be used, because the size of a laser beam is increased in both the horizontal and vertical dimensions. 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. When the SafetyScan lens is used correctly, the laser beam is unchanged above the heads of the audience, so the “marbling” effect seen in fog remains, and the spectacle, brilliance and drama of an audience scanning laser show are retained. Mirror targeting can also be performed above the heads of the audience.

A SafetyScan lens can easily be mounted directly to the front of any laser projector, either using a mount from Pangolin or using a self-made mounting arrangement. 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 in a reliable manor, the result is a show that can be more powerful, and also much safer and much more pleasant to view.

In addition to the information provided below, Pangolin has also produced a 15-minute video showing how to mount the lens, how to perform safety measurements, and the resulting laser shows.

Selecting the proper lens

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

The effective projected divergence, and thus, the spot size in the audience caused by the SafetyScan lens, depends on the incoming beam divergence (i.e. divergence before the lens), and the beam quality parameter (M2) of the incoming laser beam. It is important to understand that the better the beam quality (lower values of M2), the less of the effect that the SafetyScan lens will have on the laser beam divergence. For a detailed explanation of M2, see the Wikipedia article here: http://en.wikipedia.org/wiki/M_squared

Using the tables

Below you will find 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.

It is important to understand that the tables below represent theoretical values based on Gaussian beam physics. Since real-world lasers usually have less than ideal beam characteristics, it means that 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 M2 of your laser. Then choose a lens that provides the desired spot size.

Note that Pangolin strongly 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. As implied by the License Agreement and Limited Warranty below, PANGOLIN WILL NOT BE HELD LIABLE FOR MIS-APPLICATION OF THE SAFETY-SCAN LENS OR LENS MOUNT.

Use with Lasers having an M² of 1.2

When the beam quality (M²) is close to 1.0, it represents a near perfect, Gaussian beam. Lasers with this kind of beam quality may include lasers that use gases including Argon, Krypton, Helium-Neon, etc. Coherent Optically-Pumped Semiconductor Lasers also have very good beam quality with low M². Some low power, high quality DPSS lasers may also have M² of around 1.2.

<u>Laser beam with 1.0 milliradian full-angle divergence and M² of 3</u>
(Spot size at the exit aperture of the projector = 1.99 mm)

Distance in Meters	5	10	15	20	25	30	35	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

<u>Laser beam with 2.0 milliradian full-angle divergence and M² of 1.2</u>
(Spot size at the exit aperture of the projector = 0.64 mm)

Distance in Meters	5	10	15	20	25	30	35	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

<u>Laser beam with 3.0 milliradian full-angle divergence and M² of 1.2</u>
(Spot size at the exit aperture of the projector = 0.79 mm)

Distance in Meters	5	10	15	20	25	30	35	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

Distance in Meters	5	10	15	20	25	30	35	Divergence
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

Use with Lasers having an M² of 3.0

Lasers with M² 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 M2 of 3
(Spot size at the exit aperture of the projector = 1.99 mm)

Distance in Meters	5	10	15	20	25	30	35	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 M² of 3
(Spot size at the exit aperture of the projector = 1.11 mm)

Distance in Meters	5	10	15	20	25	30	35	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 M² of 3
(Spot size at the exit aperture of the projector = 1.00 mm)

Distance in Meters	5	10	15	20	25	30	35	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

Distance in Meters	5	10	15	20	25	30	35	Divergence
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

Use with Lasers having an 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)

Distance in Meters	5	10	15	20	25	30	35	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)

Distance in Meters	5	10	15	20	25	30	35	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)

Distance in Meters	5	10	15	20	25	30	35	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

Distance in Meters	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**Divergence**
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

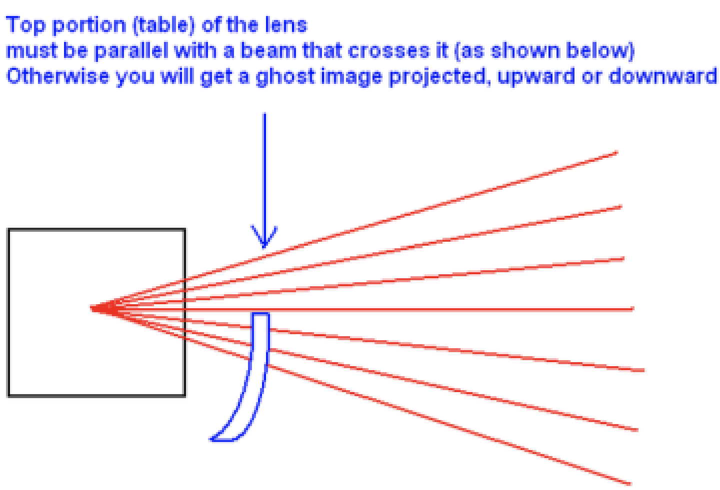
Installing the lens on a projector

Normally, the SafetyScan lens is mounted outside of a laser projector, directly in front of the exit aperture, as securely as possible. However, the lens may also be mounted inside the projector for greater security. When mounted outside, ideally a lens mount should be used which provides three degrees of adjustment. Pangolin sells, and has produced engineering drawings of such a mount that provides all three degrees of adjustment. The mount designed by Pangolin is described in the next chapter. Each degree 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).

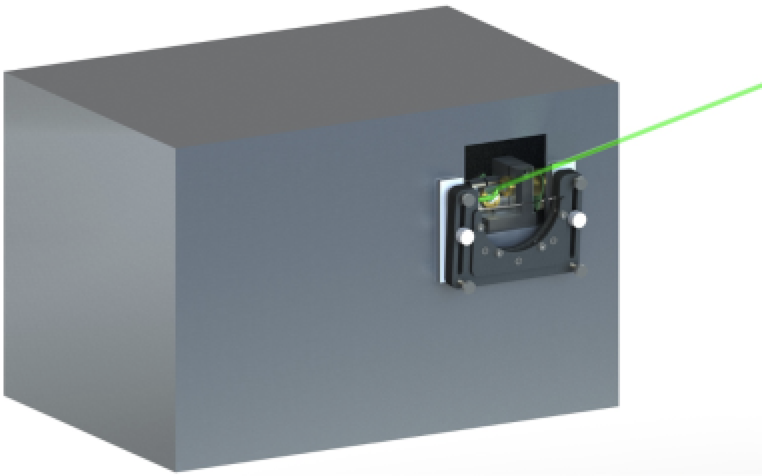
The third degree of adjustment is tilting the lens about the split at the top. If the top portion of the lens is at an angle with respect to the light coming from the X-Y scanners, there will be a kind of "ghost image", which is a reflection off of the top surface of the lens. The lens angle should be 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.



As mentioned above, we produced a video which explains all three degrees of lens adjustment (starting around time 11:20) here: http://www.youtube.com/watch?v=ooZ1C5gL7FA

Lens mount designed by Kvant

Kvant manufactures a lens mount that can be used to attach a SafetyScan lens to their laser projectors. A rendering of an example projector that uses a lens mount and SafetyScan lens is shown below.

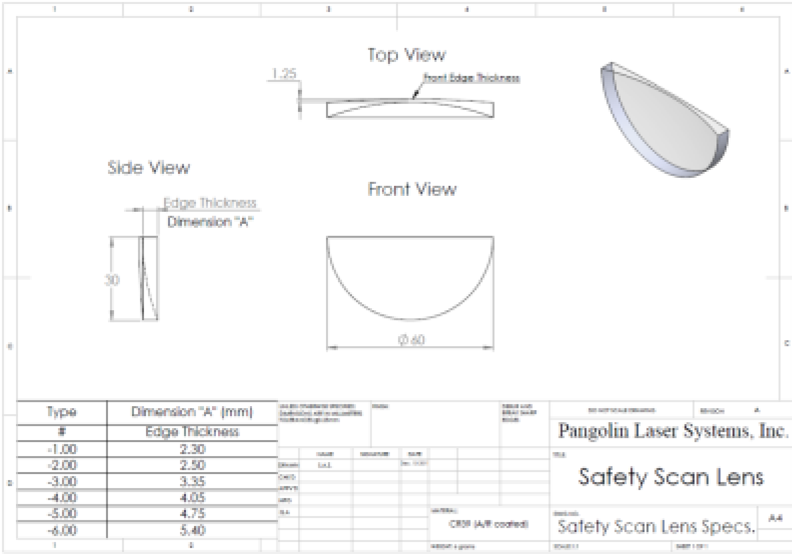


To use the SafetyScan Lens and **lens mount**, do the following:

1. Disassemble the parts from the **lens mount**.
2. Insert the SafetyScan lenses into the **lens mount**.
3. Secure the SafetyScan Lens into the **lens mount** using the screws included.
4. Attach the **lens mount** to the laser projector.
5. **Make sure that the lens is securely retained in place!**

Once you have attached the lens mount to the laser projector, **IT IS MANDATORY THAT YOU EVALUATE THE RELIABILITY AND SECURITY OF THIS ATTACHMENT, AND ENSURE THAT THE SAFETYSCAN LENS AND LENS MOUNT WILL NOT BECOME DISLODGED OR DISPLACED OVER TIME.**

Lens Engineering Drawing



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

Intellectual Property Notice

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SafetyScan lenses that are used in combination with certain projector configurations may be covered by U.S. Patent No. 8,506,087 and/or U.S. Patent No. 8,681,828.

The manufacture, use, offer for sale, or sale of laser projectors for audience scanning that incorporate SafetyScan lenses purchased from Pangolin or through a Pangolin-authorized sales channel are licensed under U.S. Patent No. 8,506,087 and U.S. Patent No. 8,681,828. No license is granted under these patents for lenses obtained from other sources.

Instruction Videos

How To Install The SafetyScan ™ Lens

SafetyScan ™ lens discussed by laserists

Theory, Installation and Use

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Last update: **2021/04/22 10:29**