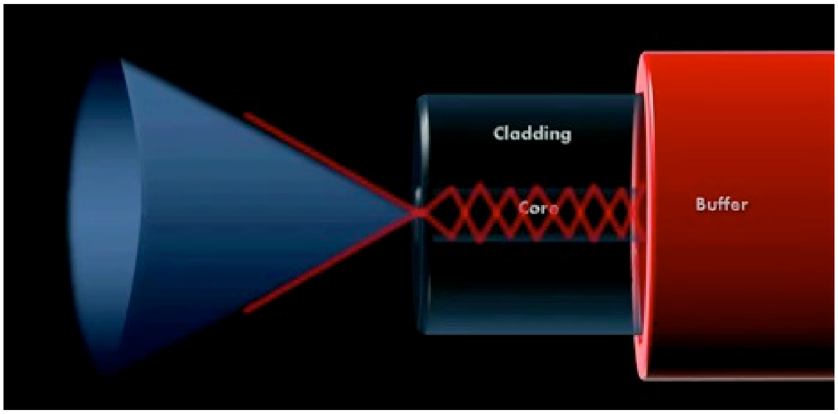
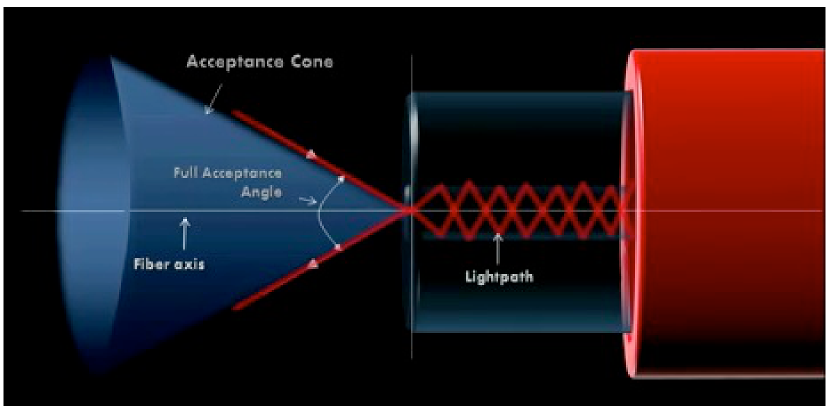
Lab #2. Measurement of Numerical Aperture of optical fibers

Introduction.

Numerical Aperture – the range of acceptance angles rotated around an axis, where light can be coupled into a waveguide such as a core of an optical fiber.



Light outside the acceptance cone can not be coupled into the fiber.

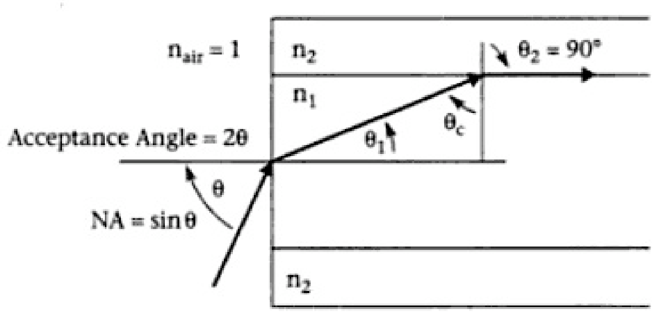


The acceptance angle and numerical aperture are figures of merit used to describe the angles associated with light propagation in optical fibers. The sine of the half-angle of the acceptance angle is known as the **numerical aperture** – **NA**.

Theoretical NA may be expressed by the equation :

$$NA = \sqrt{n_1^2 - n_2^2} \quad ,$$

where n_1 is the refractive index of the core and n_2 is the refractive index of the cladding. The refractive index of a material is defined as the ratio of the speed of light in a vacuum to the speed of light in that particular material.

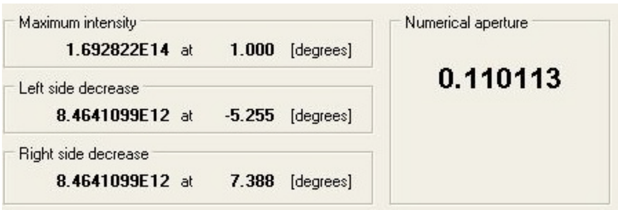


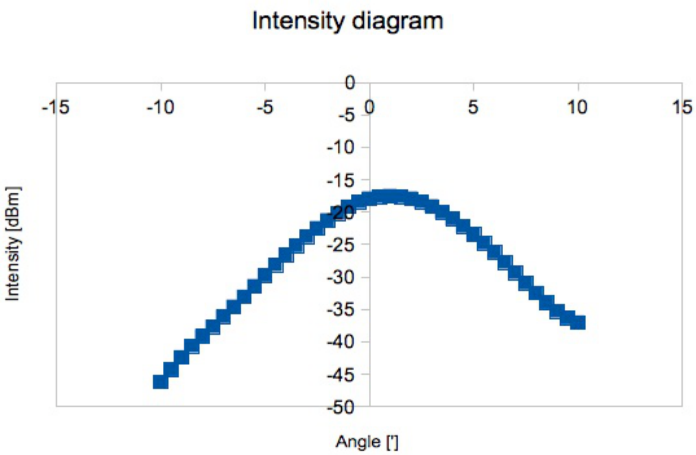
Lab #2. Measurement of Numerical Aperture of optical fibers

Measuring NA.

1. SM fiber measurement (SM-SI) 9/125µm .

Parameters: radiation source – laser; measurement mode – synchronous.





12:52:57	-7.5	1.64E+12	-37.6889
12:53:05	-7	2.35E+12	-36.1324
12:53:14	-6.5	3.33E+12	-34.624
12:53:23	-6	4.74E+12	-33.0868
12:53:31	-5.5	6.91E+12	-31.4453
12:53:50	**-5**	**1.01E+13**	**-29.8066 critical**
12:53:59	-4.5	1.48E+13	-28.1504
12:54:08	-4	2.09E+13	-26.6438
12:54:16	-3.5	2.90E+13	-25.216
12:54:25	-3	4.01E+13	-23.8087
12:54:34	-2.5	5.41E+13	-22.5064
12:54:43	-2	7.15E+13	-21.299
12:54:51	-1.5	9.20E+13	-20.2044
12:55:09	-1	1.16E+14	-19.1917
12:55:18	-0.5	1.38E+14	-18.4366
12:55:27	0	1.55E+14	-17.9416
12:55:35	0.5	1.66E+14	-17.6494
12:55:45	**1**	**1.69E+14**	**-17.5559 max**
12:55:53	1.5	1.66E+14	-17.652
12:56:02	2	1.55E+14	-17.9452
12:56:11	2.5	1.38E+14	-18.4384
12:56:19	3	1.17E+14	-19.1445
12:56:28	3.5	9.51E+13	-20.0588
12:56:37	4	7.54E+13	-21.0667
12:56:56	4.5	5.78E+13	-22.2237
12:57:05	5	4.33E+13	-23.4778
12:57:14	5.5	3.18E+13	-24.8141
12:57:22	6	2.30E+13	-26.2288
12:57:31	6.5	1.62E+13	-27.7594
12:57:40	**7**	**1.12E+13**	**-29.3635 critical**
12:57:48	7.5	7.69E+12	-30.9837
12:58:07	8	5.42E+12	-32.5031
12:58:15	8.5	3.85E+12	-33.9872
12:58:24	9	2.84E+12	-35.3038
12:58:33	9.5	2.23E+12	-36.3505
12:58:42	10	1.90E+12	-37.0449

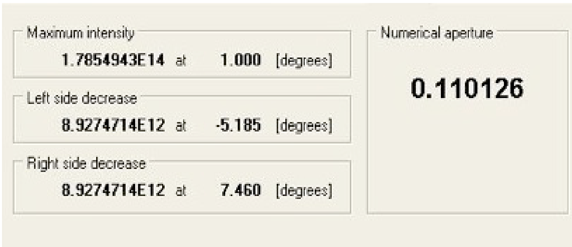
Numerical aperture calculated

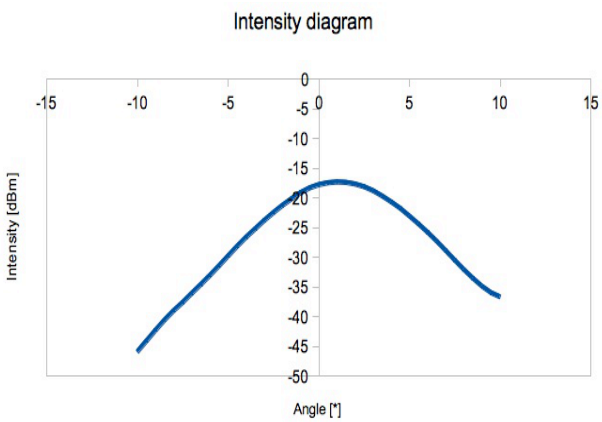
NA=n_0*sinΦm=1*sin 6˚ = 0,104

Lab #2. Measurement of Numerical Aperture of optical fibers

2. SM fiber measurement (SM-SI) 9/125µm .

Parameters: radiation source – laser; measurement mode – continual.





time	angle [deg]	intensity [au]	intensity [dBm]
12:39:11	-10	2.48E+11	-45.8918
12:39:20	-9.5	3.77E+11	-44.0753
12:39:29	-9	5.71E+11	-42.2791
12:39:37	-8.5	8.50E+11	-40.5488
12:39:55	-8	1.22E+12	-38.9936
12:40:04	-7.5	1.68E+12	-37.5845
12:40:13	-7	2.39E+12	-36.0601
12:40:21	-6.5	3.37E+12	-34.5682
12:40:30	-6	4.78E+12	-33.0482
12:40:39	-5.5	6.91E+12	-31.446
12:40:58	**-5**	**1.01E+13**	**-29.7934 critical**
12:41:07	-4.5	1.47E+13	-28.1571
12:41:15	-4	2.10E+13	-26.6102
12:41:25	-3.5	2.91E+13	-25.199
12:41:33	-3	4.03E+13	-23.7884
12:41:42	-2.5	5.44E+13	-22.483
12:41:51	-2	7.21E+13	-21.2638
12:41:59	-1.5	9.31E+13	-20.1526
12:42:17	-1	1.18E+14	-19.1237
12:42:26	-0.5	1.42E+14	-18.3185
12:42:35	0	1.61E+14	-17.7819
12:42:44	0.5	1.73E+14	-17.4568
12:42:53	**1**	**1.79E+14**	**-17.3244 max**
12:43:03	1.5	1.76E+14	-17.3928
12:43:11	2	1.65E+14	-17.663
12:43:20	2.5	1.49E+14	-18.1243
12:43:29	3	1.27E+14	-18.7929
12:43:38	3.5	1.04E+14	-19.6874
12:43:47	4	8.22E+13	-20.6938
12:43:55	4.5	6.40E+13	-21.7786
12:44:13	5	4.76E+13	-23.0624
12:44:22	5.5	3.51E+13	-24.3894
12:44:31	6	2.54E+13	-25.7917
12:44:39	6.5	1.80E+13	-27.28
12:44:48	**7**	**1.25E+13**	**-28.8688 critical**
12:44:57	7.5	8.62E+12	-30.4889
12:45:17	8	5.99E+12	-32.0681
12:45:26	8.5	4.28E+12	-33.5259
12:45:34	9	3.14E+12	-34.8771
12:45:43	9.5	2.44E+12	-35.9597
12:45:52	10	2.08E+12	-36.6625

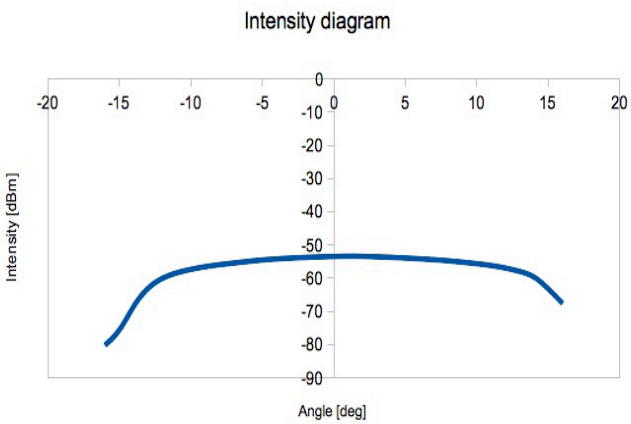
Numerical aperture calculated

$NA=n_0*\sin\Phi m=1*\sin 6^\circ = 0,104$

Lab #2. Measurement of Numerical Aperture of optical fibers

3. MM fiber measurement.

Parameters: radiation source – LED; measurement mode – continual.



time	angle [deg]	intensity [au]	intensity [dBm]
12:08:17	-16	9.35E+07	-80.1353
12:08:26	-15	2.70E+08	-75.5356
12:08:44	-14	1.37E+09	-68.4721
12:08:54	**-13**	**4.74E+09**	**-63.0808 critical**
12:09:03	-12	9.43E+09	-60.0957
12:09:20	-11	1.38E+10	-58.4293
12:09:29	-10	1.77E+10	-57.3672
12:09:39	-9	2.12E+10	-56.5735
12:09:48	-8	2.45E+10	-55.9582
12:09:57	-7	2.74E+10	-55.4607
12:10:06	-6	3.06E+10	-54.9806
12:10:16	-5	3.38E+10	-54.5491
12:10:25	-4	3.64E+10	-54.2253
12:10:34	-3	3.86E+10	-53.9723
12:10:43	-2	4.04E+10	-53.774
12:10:52	-1	4.19E+10	-53.6161
12:11:02	0	4.32E+10	-53.485
12:11:11	**1**	**4.40E+10**	**-53.4112 max**
12:11:20	2	4.36E+10	-53.4519
12:11:29	3	4.23E+10	-53.5824
12:11:38	4	4.07E+10	-53.7435
12:11:48	5	3.89E+10	-53.9441
12:11:57	6	3.68E+10	-54.1884
12:12:06	7	3.46E+10	-54.4558
12:12:15	8	3.21E+10	-54.7822
12:12:25	9	2.91E+10	-55.2021
12:12:34	10	2.62E+10	-55.6538
12:12:43	11	2.32E+10	-56.1934
12:12:52	12	1.94E+10	-56.9628
12:13:01	13	1.54E+10	-57.9656
12:13:11	14	1.05E+10	-59.6455
12:13:30	**15**	**4.64E+09**	**-63.1782 critical**
12:13:39	16	1.70E+09	-67.5353

Numerical aperture calculated

$NA=n_0 \cdot \sin\Phi m=1 \cdot \sin 14^\circ = 0{,}242$

Lab #2. Measurement of Numerical Aperture of optical fibers

Conclusions.

1. Is the automatic calculation more precise than your calculation?

In our calculation we operated with discrete values and always used rounding. It means we have got rough values in the result. Yes, automatic calculation is more precisely.

2. Is the laser suitable for MM fibers?

Only wide-spectrum lasers could be used in MM fibers measurement.

3. Compare results with official documentation.

SM-SI NA=0.08-0.1, theoretical input angle = 4.6-5.75
MM-GI NA=0.2, theoretical input angle is 11.5

Our results for single mode fiber are very close to mention above official. For multi mode fiber there is a bit difference. Perhaps because of discrete values in the measurements we've got calculation errors.