Fiber test

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Contents

1 Experimental error test

These test are performed to test the error caused from the test system, which may cause the instability of test result with repeated measurement. The LED stability decrease less than 1%/hour, which is not described here.

1.1 The light yield as a function of distance from WLS fiber end to PMT

Motivation: For the fiber test, sometimes there is unperceived air gap between fiber and PMT, which may influence the light collection, such as align 4 fiber ends of preshower to PMT.

Test Process: refer to Fig.1.

Test result: Refer to Table 1 and Fig.2.

Conclusion: the light loss for the fiber-PMT distance below 5mm could be ignored.

Discussion and note:

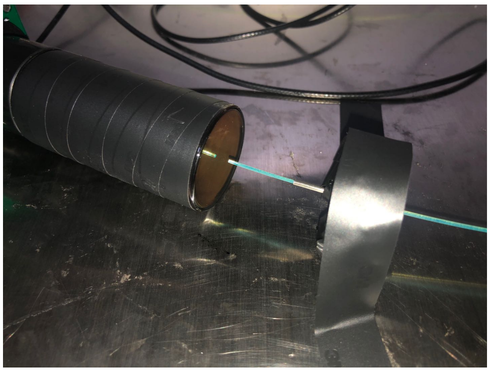

Figure 1: Distance test setup. The fiber is fixed, the distance is changed by moving the PMT.

Distance from WLS fiber end to PMT(mm)	ADC channel
0.1	2093
1	2092
3	2092
5	2043
10	1991
15	1854
20	1641
25	1408
30	1118
35	477

Table 1: The light yield as a function of distance from WLS fiber end to PMT

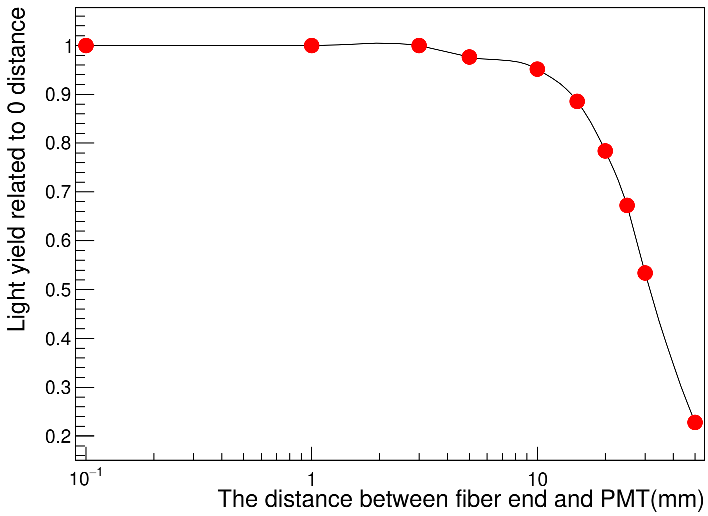

Figure 2: The relative light collection ratio as a function of fiber-PMT distance.

- The test only perform one time, because I think the result is good enough and reasonable.
- This result only works for fiber that located at the center of PMT, other location is not considered in this test.

- With my understanding, for short distance, almost all the light from fiber end could hit the PMT window, however the low gain on the edge of PMT window make the light yield lower.
- The light loss comes from two factor: low gain on the PMT window edge and undetected photons that have large angle.
- Since the light angle that at the fiber end is small, no total reflection, so optical grease is not necessary.

1.2 The light yield influence from fiber polishing quality

Motivation: the polishing quality apparently influence the light yield, and the quality could be significantly recognized from direct-eye-view. In the test, each fiber may have different polishing quality, even if they are polished at the same time, which make the result is confused. To check the impact of polishing to light yield loss, we need to test the relative light yield for different polishing method, and also the error using same method.

Test Process: Total 3 fibers of BCF91A-SC that one end is already polished by factory are tested, and another one fiber used as reference to test the light variation in the test process. One end that coupled to PMT of each fiber is polished by different method, the other end is just polished by ordinary abrasive paper roughly.

Four different methods are used: "perfectly" polished by factory, ordinary abrasive paper, fine 1 μm diamond abrasive paper and ADS[1] polishing paper.

The original factory polishing fiber is test firstly, then it's polished by other 3 methods subsequently. These three methods are polished by hand manually, no other tool is applied.

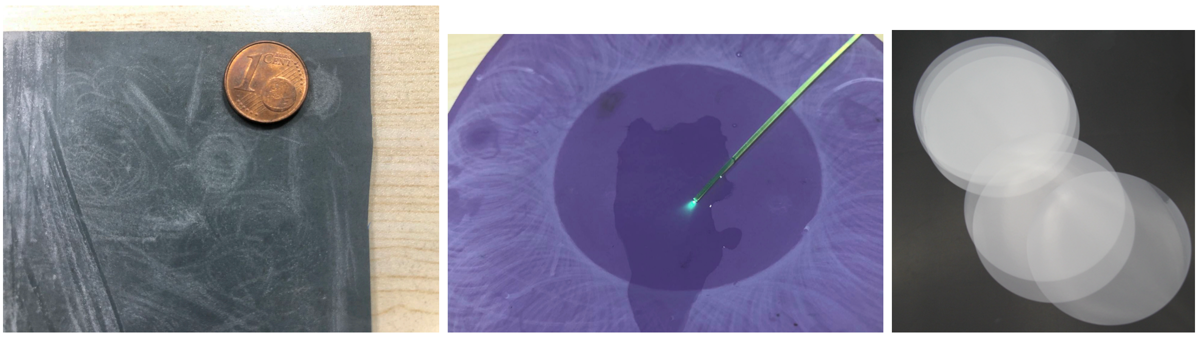

Figure 3: From left to right: ordinary abrasive paper, fine 1 μm diamond abrasive paper and ADS polishing paper.

Test result: refer to Table 2.

Conclusion: Base on personal polishing quality control, which may will improve, the 1 μm diamond polishing result is nearly equal to the factory "perfect" polishing, additional ADS polishing has on significant improvement. **The 1 μm diamond polishing method could be practically used in small batch fiber polishing.**

We have 5 kinds fibers: BCF91A-SC, BCF91A-MC, Y11-MC, BCF98-SC and BCF98-MC. In the polish process of following works, only BCF91A-MC is not good as others, shown in Fig.4.

Discussion and note:

[1] ADS is the type name of polishing paper, made by SiO_2

No.	Factory	Ordinary abrasive paper	1 μm diamond	ADS
1	2188	1745,1689,1674	2039,2103	2004,2040
2	2122	1656,1581,1653	2059,2138	2156 ,2138
3	2063	1605,1731,1663	2041,1932[a]	2022
ratio	1	~0.8	~0.98	-

[a] The other end is polished by mistake. (Bad polishing quality could slightly improve light reflection.)

Table 2: Fiber polishing result, the number shown in table is the ADC channel. Before the second test of 1 μm diamond, fiber is polished with more time.

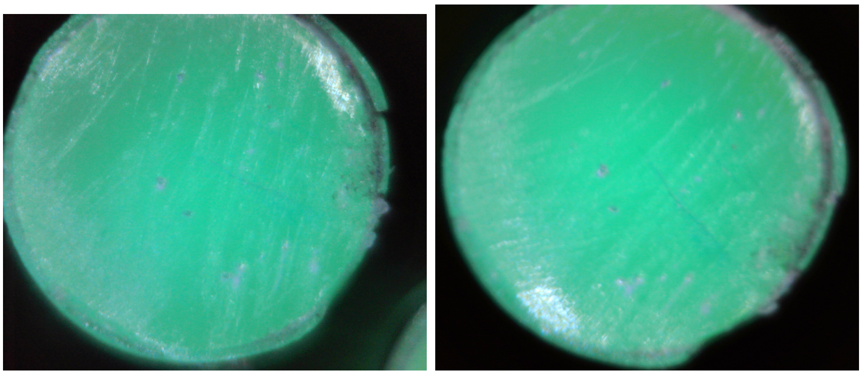

Figure 4: Left: one polished end of BCF91A-SC. Right: one polished end of BCF91A-MC. There are more cracks.

- The surface of fiber end after polishing is not perpendicular to the fiber, which is inevitable by hand polishing.
- The polishing quality could be examined by direct-eye-view, a good polishing end has a clear mirror reflection effect.
- The machine polishing method in SDU is not tested. The machine polishing use both 1 μm diamond and ADS abrasive paper, but it's a "hard" process that not as soft as hand control, and the quality is equal or worse than the 1 μm diamond polishing shown above.
- The 20% light loss of ordinary abrasive paper could regarded as a rather bad result, so to evaluate the light loss from polishing, a normal polishing quality will lead to less than 10% light loss roughly.
- All the other fibers shown in this article are polished by 1 μm diamond method manually.

2 WLS fiber light yield test

Three kinds WLS fibers are tested: Y11-MC, BCF91A-SC and BCF91A-MC. We tested the fibers through two methods: Preshower light yield test and LED test. The Preshower test has the real scintillating light but the fiber will be bent with a non-negligible bending angle. The LED test is a convenient test that has enough statistics in short time, but the photon spectrum may not corresponding to the scintillating light.

These three kinds WLS fiber can't be recognized from appearance. However, the BCF91A-MC has worse polishing quality. We use same manual polishing method, Y11-MC and BCF91A-SC could achieve good polishing quality as described before. The fiber end of BCF91A-MC is impossible to be polished manually to form a clear ”mirror” end as the other two kinds, and there are small ”cracks” at the end surface. so there is a slightly light loss of BCF91A-MC from polishing, the value of which is not sure now. I suspect the core material of fiber is different (the material of BCF91A-MC may more ”soft”).

Only 8m un-cut Y11-MC left in SDU now, few Y11 test will be performed in future.

2.1 LED test

Two 0.8m WLS fibers of each kind are tested by LED, each end is polished manually. Test setup is shown in Fig.5.

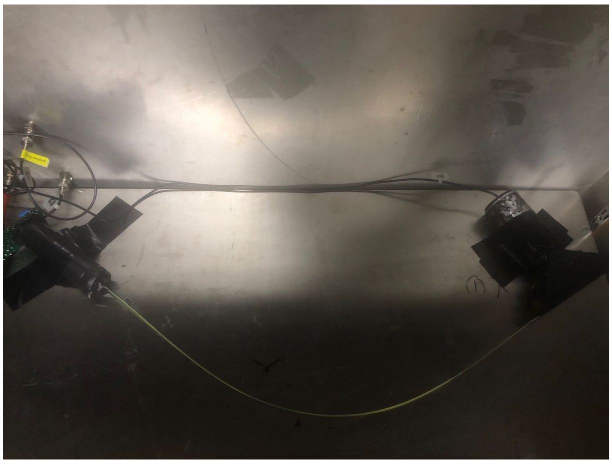

Figure 5: The LED test setup.

WLS fiber kind	Fiber No.	Test result(ADC channel)
BCF91A-SC	1	1337
	2	1326
BCF91A-MC	1	1301
	2	1347
Y11-MC	1	1947
	2	1898

Table 3: LED test result.

Result: The BCF91A-SC and BCF91A-MC have similar light yield, 44% ((1947+1898)/(1337+1326)-1) more light yield of Y11-MC compared to BCF91A-SC.

(In fact, we did repeated test with these fibers, however, the second and third test result show a worse light yield of all fibers. This test will repeat in following days.)

2.2 Preshower cosmic ray test

Test process:

2 fibers and each 2.5 turns are embedded into grooves. As shown in the left of Fig.6, four fiber ends are coupled to PMT directly. Two preshowers are wrapped by Tyvek(0.275mm) and ESR separately. Total three preshowers are tested at the same time: two used for fiber test and one used for wrapping test, which is shown in the right of Fig.6.

Test result:

Figure 6: Left: Preshower with fiber wrapped by ESR. Right: Preshower test setup in light-tight box. 4 preshowers are stacked together in the center of picture.

Two groups(4 fibers) of each kind are tested. Each test has more than 3000 triggered events, fitted roughly by Landau distribution. Result is shown in Table 4.

WLS fiber kind	Group	Tyvek(charge)	Relative light yield	ESR(charge)	Relative light yield
BCF91A-SC	1	135	**1**	64	**1**
	2	155.7	**1.15**	61	**0.95**
BCF91A-MC	1	139.5	**1.03**	60	**0.94**
	2	131.5	**0.97**	54.7	**0.85**
Y11-MC	1	233	**1.72**	105.3	**1.64**
	2	225	**1.67**	106.4	**1.66**

Table 4: Preshower test result, result is shown in the unit of charge.

Result shows the BCF91A-SC and BCF91A-MC have similar light yield, and Y11-MC has about 67% more light yield compared to BCF91A-SC.

2.3 Result discussion

For BCF91A-MC, I don't think the polishing quality is the main reason that the light yield is not what we expected, the light loss from polishing would be about 10%, which is at most 20%.

For Y11-MC, the theoretical calculation shows it has 70%(5.35%/3.15%) more light yield compared to single-cladding. 44% improvement of LED test is achieved. Since the fiber is bent in preshower test, bending loss is cared. Previous result shows an about 5% light loss for 9cm diameter, shown in Fig.7, so 67% result is contributed from both double-cladding and bending loss.

3 Preshower wrapping by ESR

The preshower is wrapped by one layer of ESR or Tyvek. Thickness comparison:

- **ESR: 0.07mm**
- **Tyvek: 0.275mm** (1082D, thickest Tyvek)

This test is performed at the same test with fiber-preshower test, uses a third scintillator.

Result shows ESR has a better than 20% light yield than Tyvek for preshower warpping.

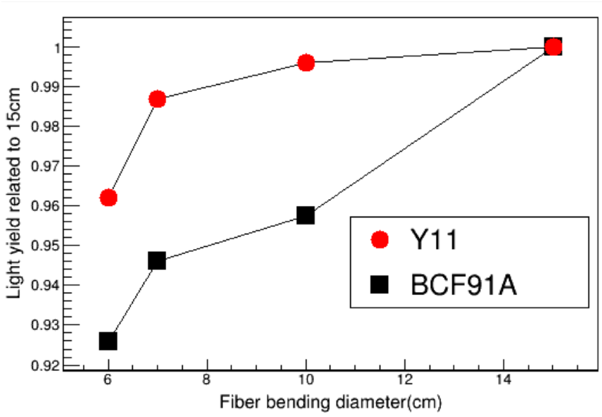

Figure 7: The bending loss comparison(Previous result). The fiber is bent with one circle for specific diameter.

Fiber	**Wrapping material**	**Charge**	**Ratio**
Y11-MC(group 1)	Tyvek	167	**1.20**
	ESR	201	
BCF91A-SC(group 1)	Tyvek	115.4	**1.25**
	ESR	144	
BCF91A-MC(group 1)	Tyvek	113.4	**1.23**
	ESR	139	

Table 5: Preshower wrapping material comparison: Tyvek Vs. ESR. (This comparison also shows the Y11 has about 40% more light than BCF91A-SC, confused. This test is not specifically used to test the fiber.)

4 Clear fiber attenuation length(preliminary test)

Two methods are applied: cutting fiber from long to short and separate single fiber test with different length. And we have two kinds clear fibers: BCF98-SC and BCF98-MC.

For the cutting method, one end is always fixed, the only change is the other end, which is cut and polished manually each time, and this method should be better than the different fiber length test, but it is based on the good manual polishing quality. Apparently, this test can't be repeated.

Both BCF98-SC and BCF98-MC have similar good polishing quality as BCF91A-SC and Y11.

4.1 Cutting method

An original 5m fiber BCF98-SC is used for test, 0.5m cut each test. Result is shown in Fig.10.

The exponent fitting result shows a 4.73m attenuation length.

4.2 Different length method

This test follows the work that presented two weeks ago, the fibers are polished by the machine. Both BCF98-SC and BCF98-MC are tested. Result is shown in Fig.9.

These fibers will be re-polished manually and re-test again.

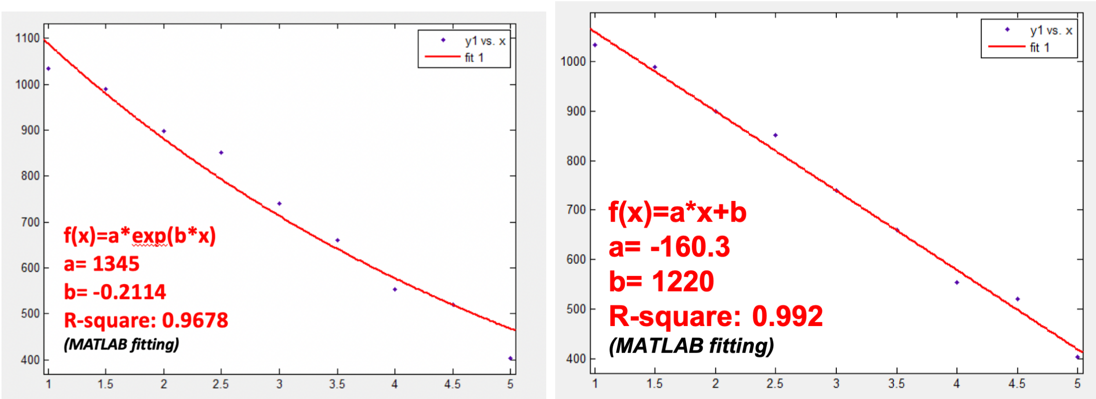

Figure 8: Left: Fitted by exponent function. right: Fitted by a linear function, which shows a better fitting than exponent.

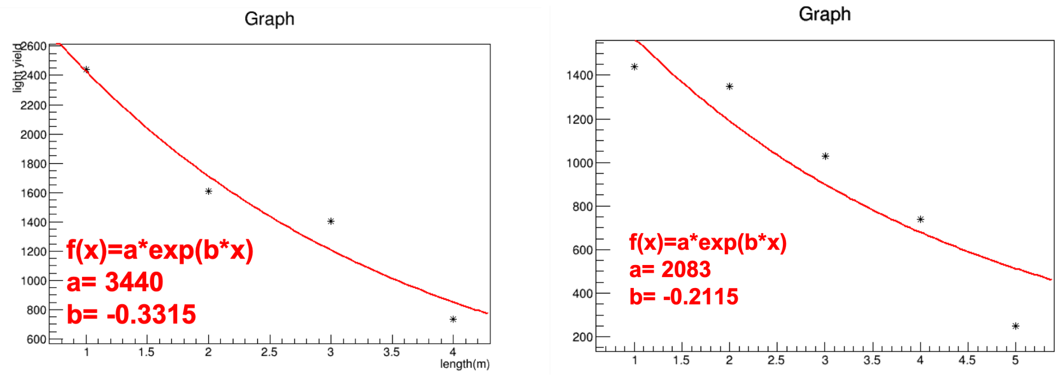

Figure 9: Left: Single-cladding BCF98-SC result fitted by exponent function. right: Multi-cladding BCF98-MC result fitted by exponent function.

5 Conclusion and todo list

Confirmed result:

- Manually polishing has good polishing quality for BCF91A-SC, Y11-MC, BCF98-SC and BCF98-MC.
- The Y11-MC has 60%+ more light yield compared to BCF91A-SC when embedded in preshower.
- ESR has a better than 20% light yield than Tyvek for preshower warpping.
- The light loss for the fiber-PMT distance below 5mm could be ignored.

Confused result: BCF91A-MC has similar light yield compared to BCF91A-SC. Need to confirm with company.

5.1 Todo List

The test shown in this presentation, but **need to repeat to confirm:**

- WLS fiber LED test.

- Clear fiber attenuation length.

To test in the following days:

- Bending loss for all 5 kinds fibers.
- Attenuation length of WLS fibers.
- Connector light loss. SC/MC -> SC/MC
- Repeat the 5-layer ESR reflector test.
- Other task?

6 BACKUP

6.1 SDU prototype module 6

The module is already assembled, and will be tested soon. The prototype will be tested with four different coatings:

- No coating.
- Tyvek.
- ESR.
- TiO_2 coating (depend on ESR result)

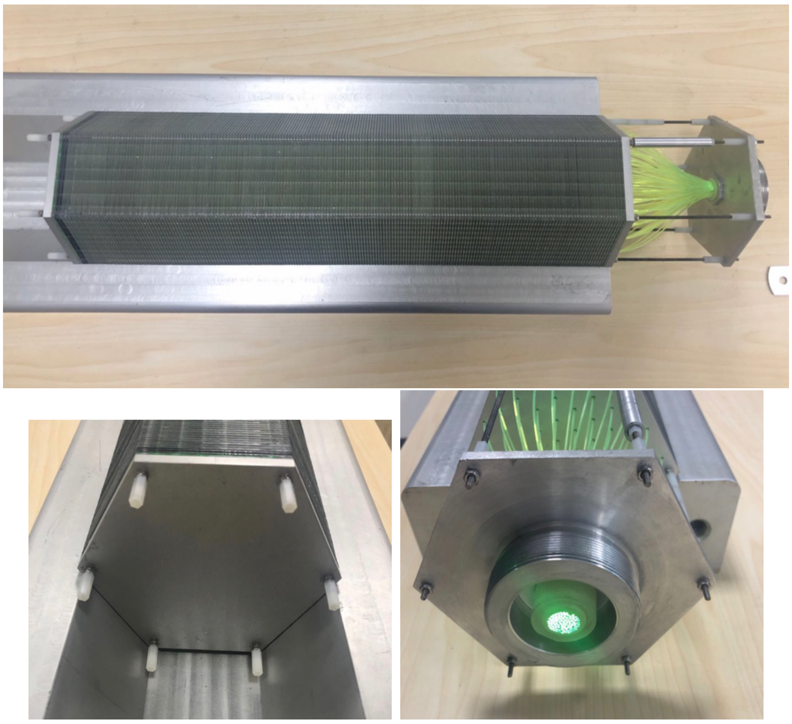

Figure 10: The picture of assembled module SDU 6.