HAWC Optical Calibration: Recent Progress at UNM

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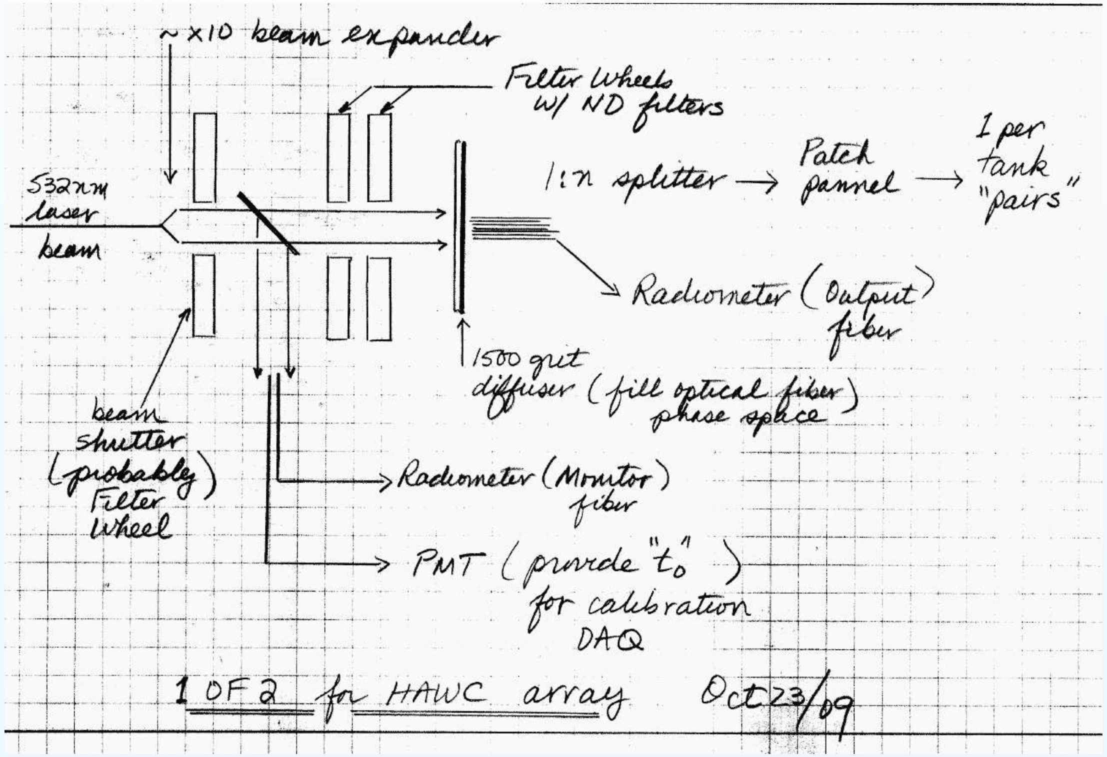
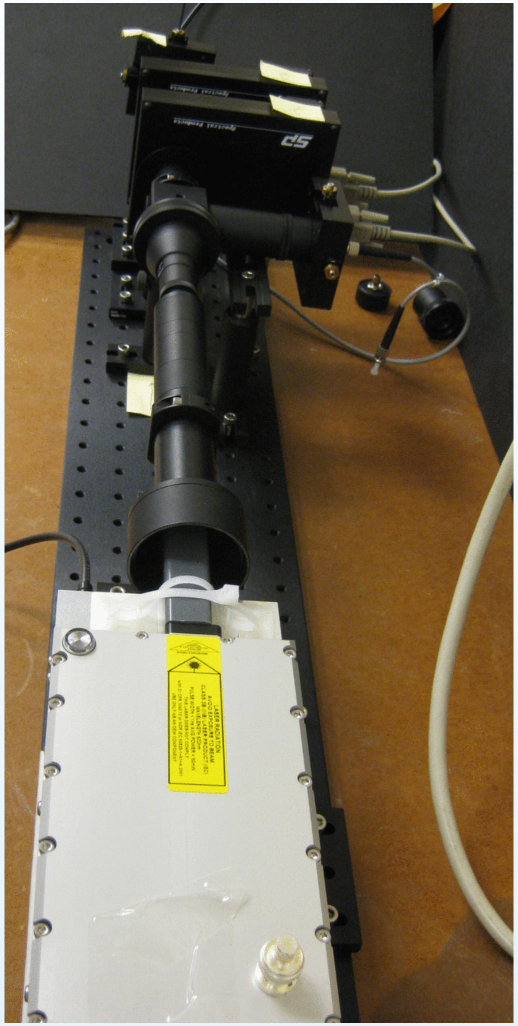
Calibration system: *laser source concept*

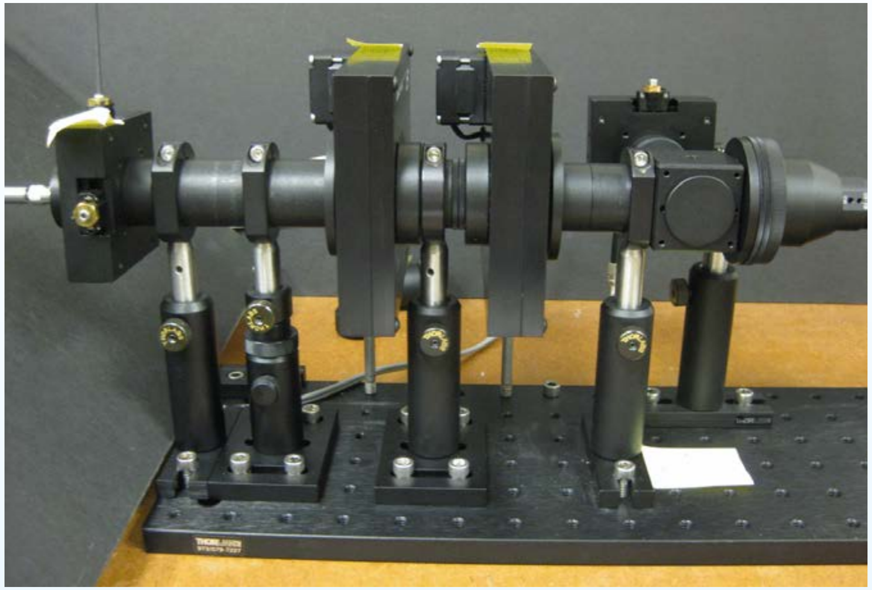


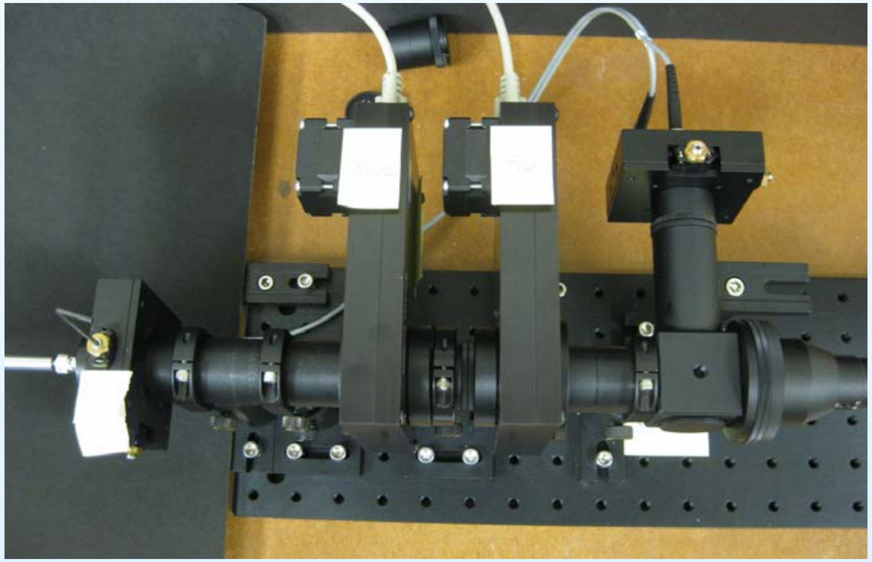
- Old sketch of light source ... *most* of this figure is unchanged but:
  1. now only one source ... so NO beam shutter
  2. 1:n splitter is probably 1:37 splitter and (20) fibers from the splitter will go to 1:16 DiCon optical switches then to the patch panel
  3. add a 1:19 splitter to the monitor path for round trip timing measurement

Calibration system: *laser source reality*



Laser light source fits on 3’ optical bench





Calibration system: *laser source automation*

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2010	216.61856	100	11	210	25	2.50E−08	5.45E−11	25	5.60E−09	2.05E−11	0.37	0.10
2010	216.61861	100	11	210	25	2.50E−08	1.00E−10	25	5.58E−09	3.30E−11	0.59	0.10
2010	216.61867	100	11	230	25	2.50E−08	3.60E−11	25	2.26E−09	3.33E−12	0.15	0.10
2010	216.61870	100	11	230	25	2.50E−08	6.40E−11	25	2.26E−09	5.18E−12	0.23	0.10
2010	216.61876	100	11	240	25	2.49E−08	9.36E−11	25	1.41E−09	5.90E−12	0.42	0.10
2010	216.61879	100	11	240	25	2.49E−08	8.41E−11	25	1.41E−09	5.74E−12	0.41	0.10
2010	216.61887	100	11	260	25	2.49E−08	8.77E−11	25	5.34E−10	3.91E−12	0.73	0.10
2010	216.61891	100	11	260	25	2.49E−08	6.79E−11	25	5.34E−10	2.36E−12	0.44	0.10
2010	216.61900	100	11	310	25	2.49E−08	6.24E−11	25	5.59E−10	2.18E−12	0.39	0.10
2010	216.61905	100	11	310	25	2.49E−08	6.51E−11	25	5.59E−10	3.16E−12	0.57	0.10
2010	216.61913	100	11	330	25	2.49E−08	7.08E−11	25	2.26E−10	3.13E−12	1.38	0.10
2010	216.61916	100	11	330	25	2.49E−08	7.62E−11	25	2.26E−10	2.35E−12	1.04	0.10
2010	216.61922	100	11	340	25	2.48E−08	9.11E−11	22	1.39E−10	4.72E−13	0.34	0.10
2010	216.61925	100	11	340	25	2.48E−08	5.67E−11	25	1.40E−10	2.57E−13	0.18	0.10
2010	216.61932	100	11	360	25	2.47E−08	7.52E−11	25	5.24E−11	2.09E−13	0.40	0.10
2010	216.61937	100	11	360	25	2.47E−08	1.20E−10	25	5.24E−11	2.82E−13	0.54	0.10
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2010	216.61951	100	11	410	25	2.49E−08	9.17E−11	25	4.44E−11	2.62E−13	0.59	0.10
2010	216.61957	100	11	430	25	2.50E−08	5.14E−11	25	1.76E−11	1.96E−13	1.11	0.10
2010	216.61961	100	11	430	25	2.49E−08	5.72E−11	25	1.76E−11	1.63E−13	0.92	0.10
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2010	216.61971	100	11	440	25	2.48E−08	9.18E−11	25	1.11E−11	3.82E−14	0.34	0.10
2010	216.61977	100	11	460	25	2.48E−08	8.83E−11	25	4.16E−12	3.08E−14	0.74	0.10
2010	216.61981	100	11	460	25	2.47E−08	9.49E−11	25	4.16E−12	3.14E−14	0.75	0.10
2010	216.61990	100	11	510	25	2.47E−08	6.50E−11	25	4.01E−12	3.02E−14	0.75	0.10
2010	216.61995	100	11	510	25	2.48E−08	6.46E−11	25	4.00E−12	2.60E−14	0.65	0.10

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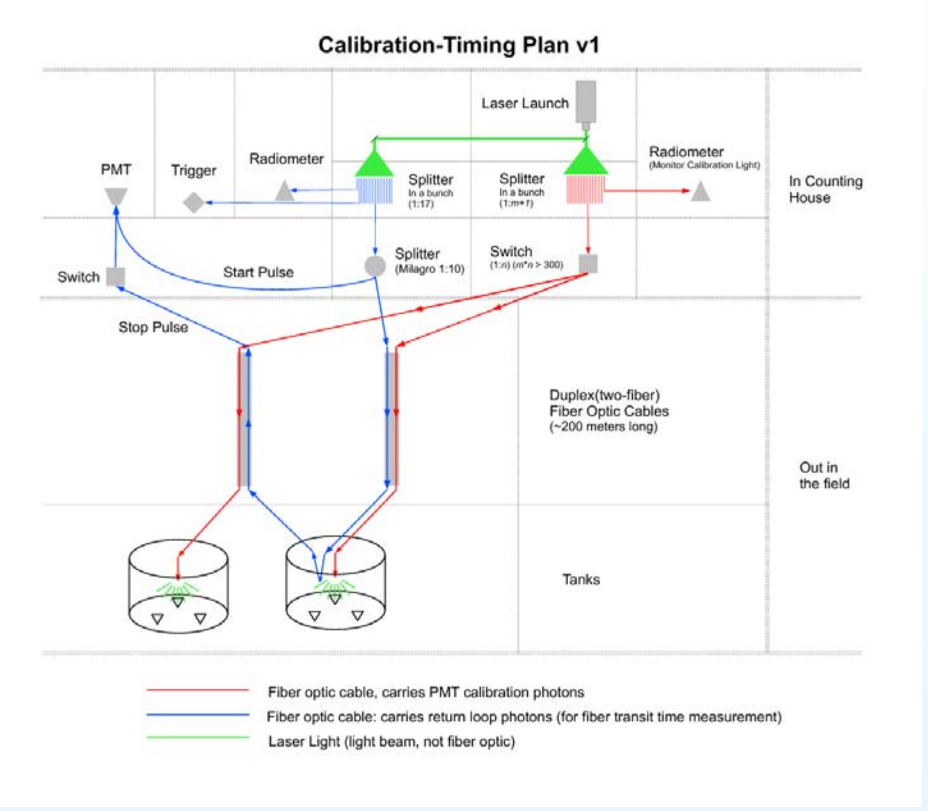
- Laser calibration now runs under computer control ... most-relevant columns:
  1. column 1,2 = year and day of calibration run
  2. column 5 = Filter Wheel positions (for up to 3 FWs)
  3. column 7,8 = monitor intensity and RMS (Joules)
  4. column 10,11 = output intensity and RMS (Joules)
  5. column 13 = period of laser pulsing (sec)

Calibration system: *1 diffuser/tank* (I)

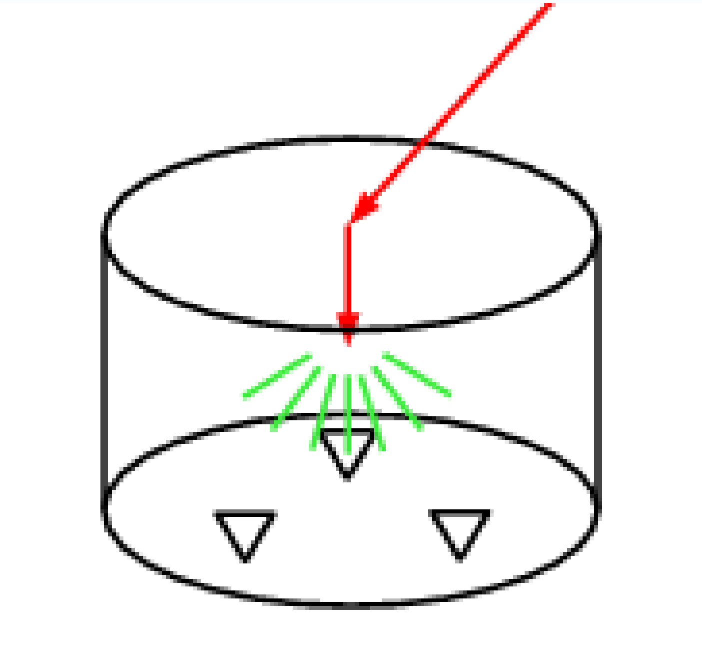


- Should we (and can we) have one optical diffuser/tank?
  1. illumination using 1 diffuser/tank may be most like photon-showers
  2. to have sufficient intensity passive splitters are replaced by DiCon switches
  3. now a fiber shown in red must run to each tank (not to a pair of tanks)
  4. round trip timing now uses light from the laser source monitor light path

Calibration system: *1 diffuser/tank* (II)

- July 2010 study of laser brightness at CSU:
  1. The HAWC laser calibration system specification is to provide light pulses (to the 900 PMTs in HAWC) sufficient to calibrate the PMTs over the signal range of: < 1PE to $\sim 10^4$ PEs.
  2. To determine if our prototype laser system for HAWC can meet these goals, pulses from the laser were used to illuminate one of the Milagro PMTs.
  3. The CSU study used a radiometer to measure the laser light pulse (before a 15m fiber taking it to a position between 2" and 12" directly above the PMT). Neutral density filters were then inserted to reduce the light intensity until we estimated that the average number of PEs (seen by the PMT) was ~ 1.
  4. Our measurements were consistent with a signal of 10^4 PEs corresponding to ~ 0.083 pJ of 532 nm light (onto the PMT). This is about $1.57\times$ the estimated light based on Hamamatsu quantum efficiency numbers.
  5. These light intensities must be increased to correct for two factors:
     (a) the light delivery efficiency to the tank: ~ 0.1 (mostly already measured)
     (b) the fraction of the diffused light accepted by the PMT: ?? 1.6×10^{-4} for 4π diffuser at 4m ?? (to be measured in CSU tank)
  6. With these efficiencies, the laser source just meets the design goals ...

Calibration system: *next studies* (I)



- The highest priority is to measure the light coupling efficiency for a single diffuser in the CSU water Cherenkov detector (tank). To do this requires:
  - ideally 3 working PMTs in the tank $+$ associated DAQ $+$ software to extract 1 PE signals
  - mounting plan for optical diffuser
  - ≥ 1 prototype diffusers
  - prototype laser light source at CSU (ideally on the Internet)

Calibration system: *next studies* (II)

- R&D on the round trip timing measurement. To do this requires:
  - fast optical sensor(s) to form the t_{start} and t_{stop} timing signals: both Thorlabs fast silicon detectors and Hamamatsu miniature PMTs will be evaluated.
  - precision time measurement instrument: examples include the Stanford Research Systems model SR620 and the Berkeley Nucleonics model 1105 shown above.

Calibration system: *summary/conclusions*

- Because most pieces of the laser calibration system can be tested in the laboratory, we are making good progress to a fi nal, working, deliverable system.

- The CSU water Cherenkov detector (tank) now allows us, over the next ?? months, to complete our system tests. This should be the basis of a technical paper on the HAWC calibration system.

- What is less known are the details of how all of the pieces will *fit* in the HAWC *calibration room*, and the actual routing (plus storage of excess cable length) of the long (600' ??) optical fi bers to the 150 tank-pairs.