# HAWC Optical Calibration: Recent Progress at UNM

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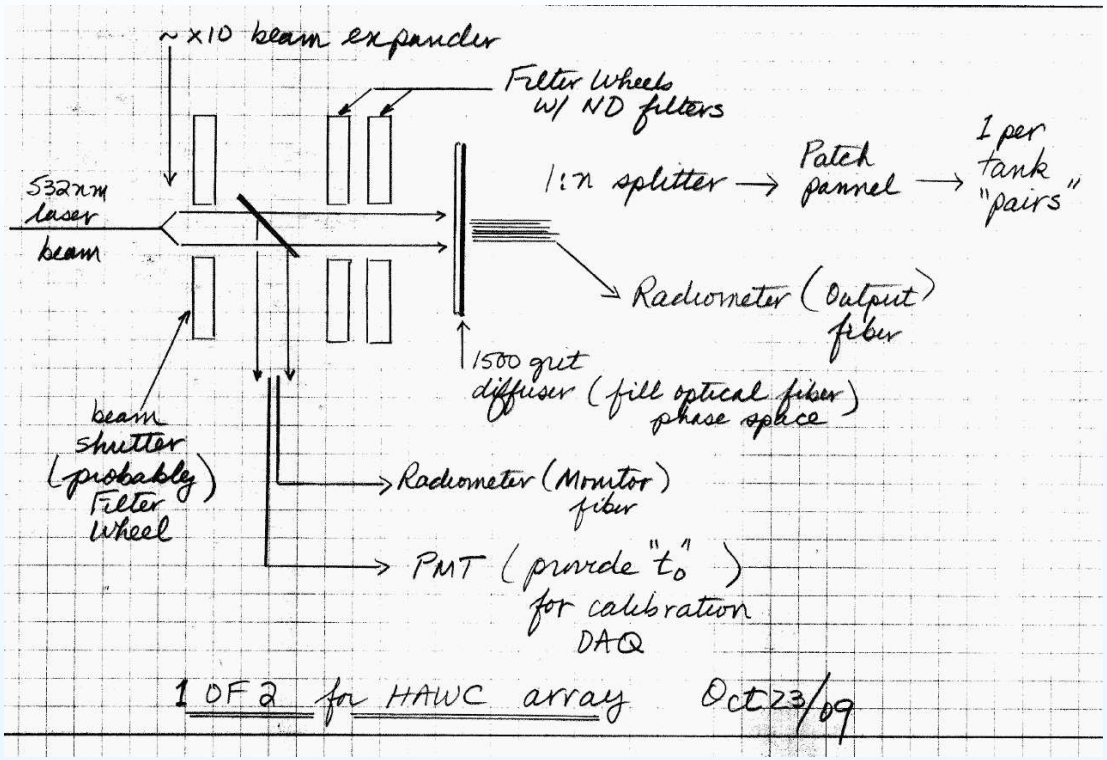
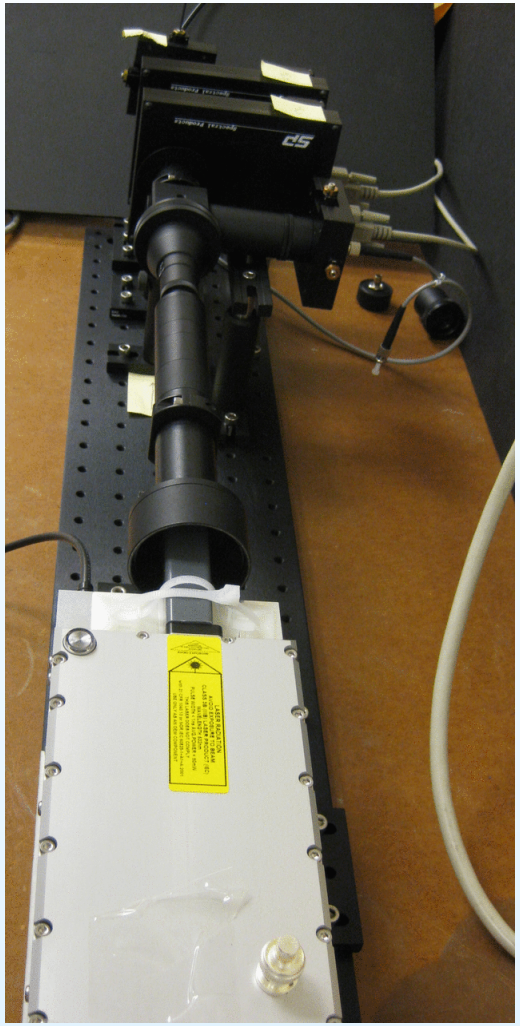
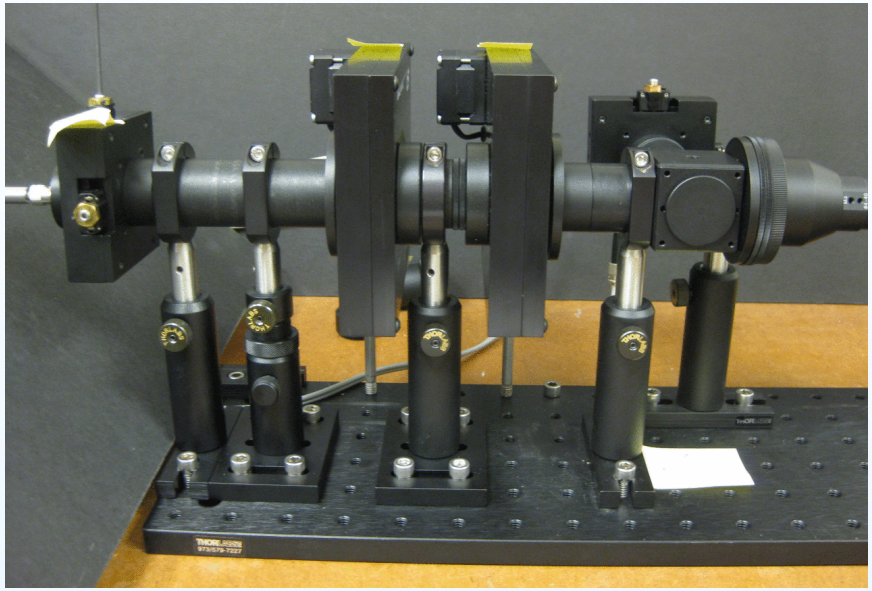
# Calibration system: *laser source concept*

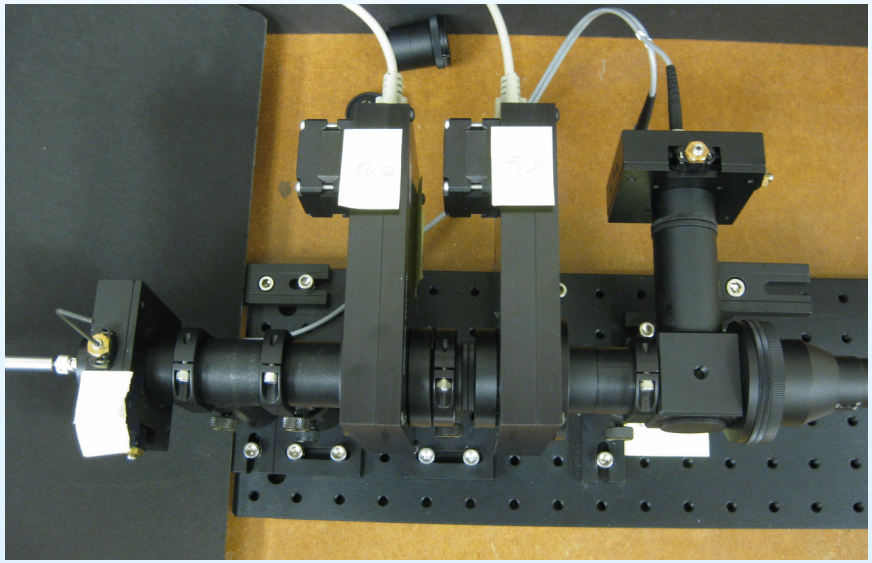



- Old sketch of light source ... *most* of this figure is unchanged but:
  1. now only one source ... so NO beam shutter
  2. 1:n splitter is probably 1:37 splitter and (20) fibers from the splitter will go to 1:16 DiCon optical switches then to the patch panel
  3. add a 1:19 splitter to the monitor 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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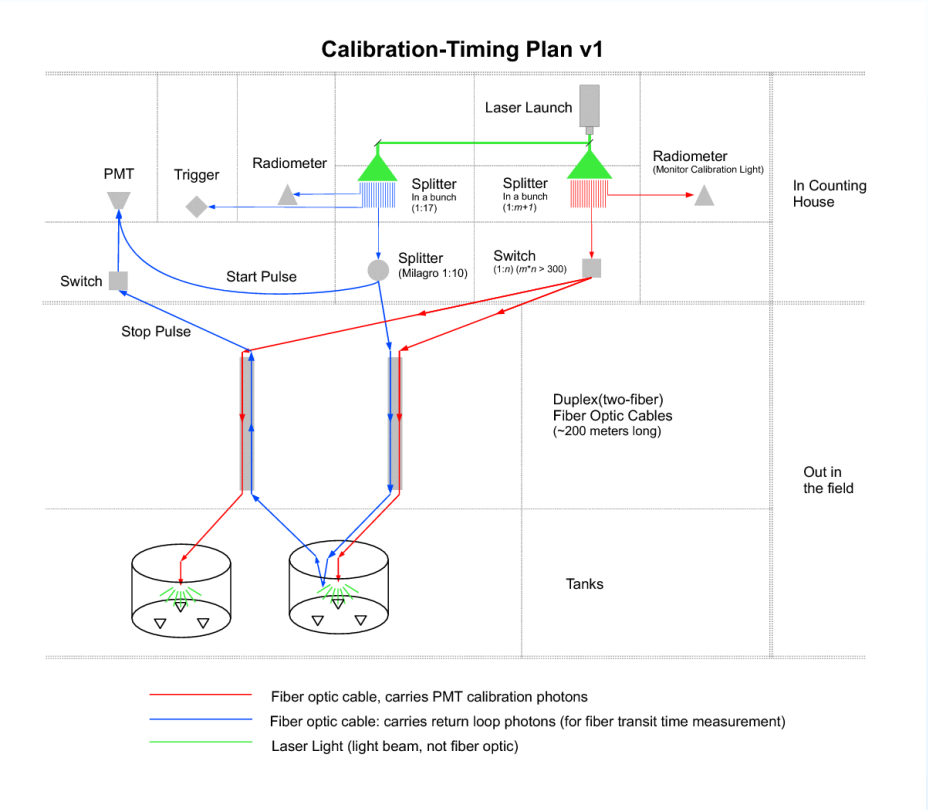
- Laser calibration now runs under computer control ... most-relevant columns:
  1. column 1,2 = year and day of calibration run
  2. column 5 = Filter Wheel positions (for up to 3 FWs)
  3. column 7,8 = monitor intensity and RMS (Joules)
  4. column 10,11 = output intensity and RMS (Joules)
  5. column 13 = period of laser pulsing (sec)

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



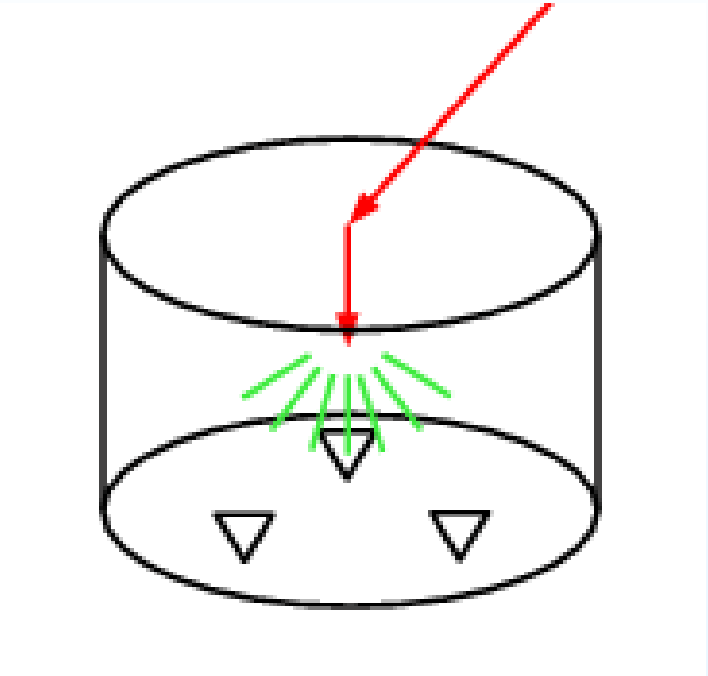

- Should we (and can we) have one optical diffuser/tank?
  1. illumination using 1 diffuser/tank may be most like photon-showers
  2. to have sufficient intensity passive splitters are replaced by DiCon switches
  3. now a fiber shown in red must run to each tank (not to a pair of tanks)
  4. round trip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

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

The University of New Mexico

- 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: $< 1$PE 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 $\sim 1$.
  4. Our measurements were consistent with a signal of $10^4$ PEs corresponding to $\sim 0.083$ 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: $\sim 0.1$ (mostly already measured)
     (b) the fraction of the diffused light accepted by the PMT: ?? $1.6 \times 10^{-4}$ for $4\pi$ 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
  - $\geq 1$ 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*

The University of New Mexico

- 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.