

HAWC Optical Calibration: 900 \rightarrow 300 Tanks

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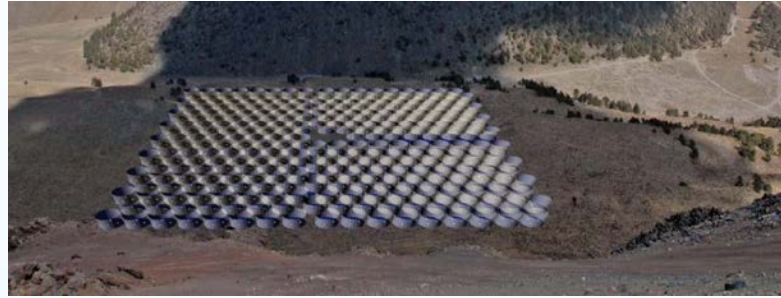
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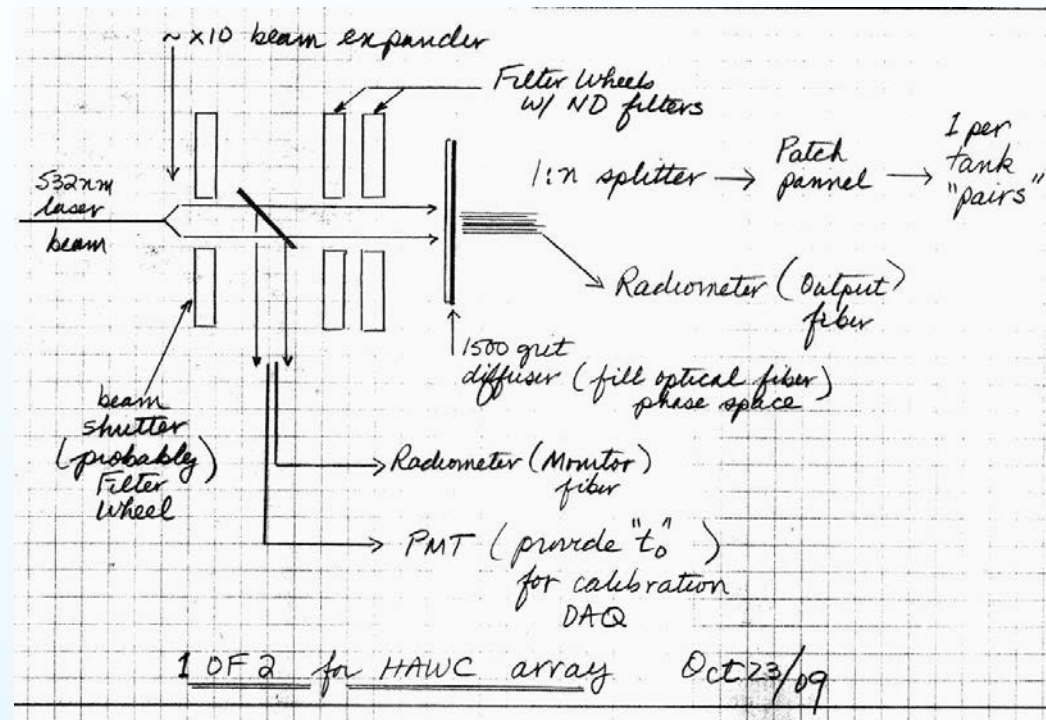
Calibration system: *baseline design*



The HAWC array is now composed of 150 **tank-pairs**:

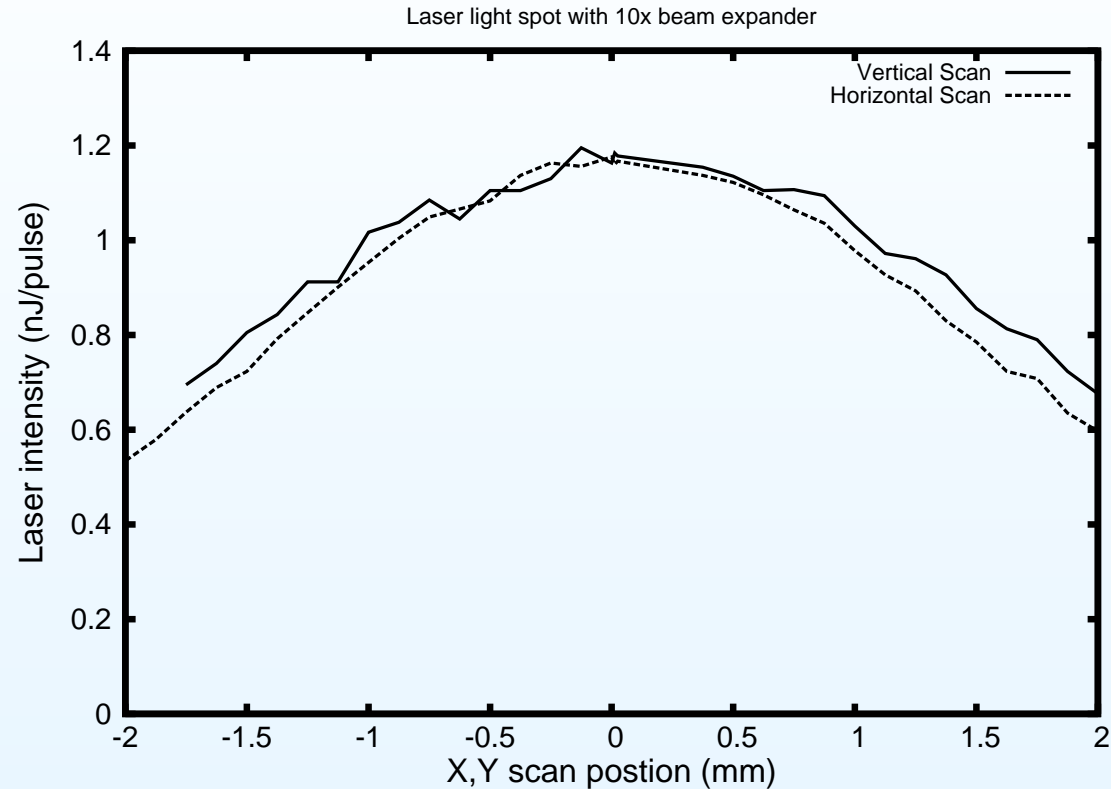
- As before we propose:
 1. two, identical laser sources: each source calibrates $\sim 1/2$ tanks
 2. lasers are coupled to optical fibers w/ beam expanders and 1:n fiber splitters
- What has changed is:
 1. one duplex optical fiber now goes to each **tank-pair** providing the calibration light to those tanks and 2-times the light path to monitor the end-to-end propagation time.
 2. at each **tank-pair** light is now split (only) 7-ways: 3 fibers to each tank and 1 fiber to provide the end-to-end time monitor.
 3. much shorter, ~ 15 m long, optical fibers go from the 1:7 splitters to a *diffuser* near each PMT.

Calibration system: *laser source (I)*



- What has changed is:
 1. time synchronization between the two (independent) laser sources now uses a PMT to define a t_0 ... that must be input to the HAWC DAQ.
 2. a beam shutter (in each laser source) ensures that calibration light comes from only one of the lasers (at any given time).
 3. a 1500 grit diffuser results in a more-uniform speckle pattern

Calibration system: *laser source (II)*



- Laser beam profile with 10x beam expander:
 1. a 1:91 optical fiber splitter (with $62.5\mu/125\mu$ optical fibers) occupies $\sim \pm 0.75\text{mm}$
 2. thus most (outgoing) signals should be within $\sim \pm 10\%$ in intensity.


Calibration system: *laser source (III)*

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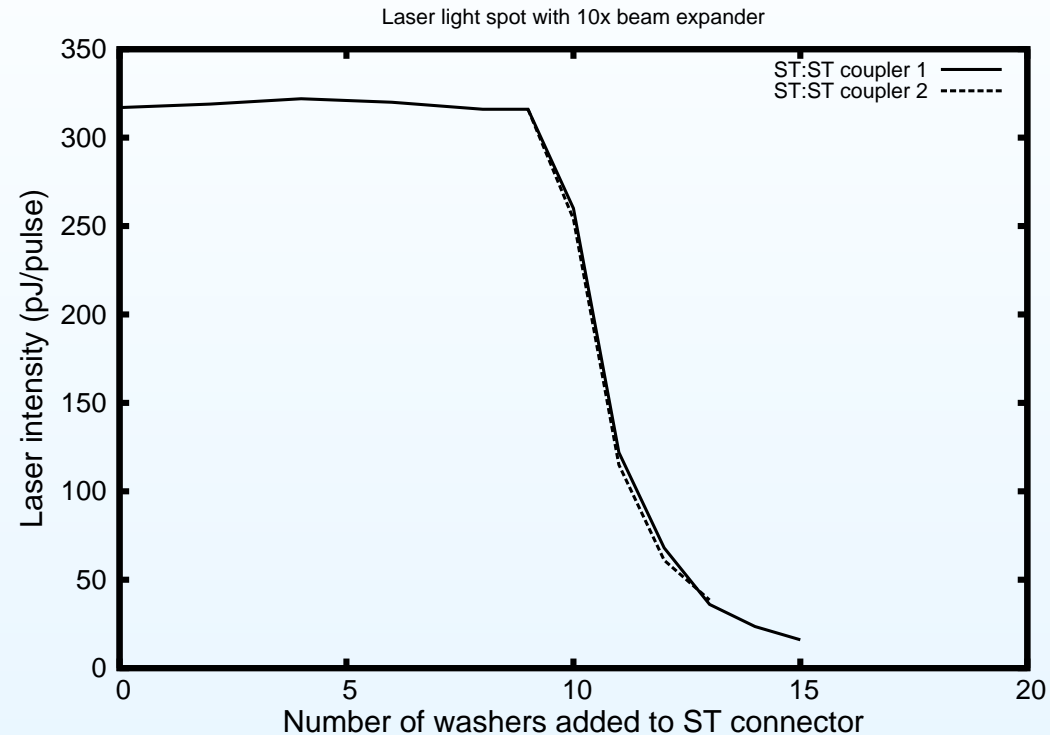
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- Possible calibration control computer:
 1. the Mac Mini can now be obtained with solid state disk drive
 2. a conventional Mac Mini computer (running UNIX) has been used to control one of the Auger FD relative calibration systems for ~ 18 months without problems.

Calibration system: *other studies*



- Mechanical adjustment of fiber intensity (or coupling into 1:n splitters):
 1. it is desirable for the return (end-to-end timing) signals to be relatively similar in amplitude.
 2. while fine control is difficult, mechanical separation of the fibers at a ST:ST coupler allows the transmitted intensity to be varied by $\sim 10\times$ per fiber ...

Calibration system: *continuing issues*

- What is the fiber to fiber uniformity and fiber (output) light intensity for **field distribution** options:
 - 1:7 optical fiber splitters, 62.5 μ m fibers, and one diffuser per PMT
 1. advantage is that the diffuser can be *as close as needed* to the PMT; the design goal is a maximum signal of $\sim 10^4$ PEs
 2. a possible dis-advantage is that there is one fiber per PMT VS one fiber per tank
 - 1:3 optical fiber splitters, 200 μ m fibers, and one diffuser per tank
 1. an advantage is that the larger fibers have smaller fiber to intensity variations
 2. the dis-advantage is that the diffuser must be $\gtrsim 2$ m from the PMTs; thus the PMT solid angle at the diffuser is small!
 3. it is unclear whether one diffuser/tank is a plus or minus in regards placement and tethering issues ...
- Or can we gain a significant ($\gg 2\times$) increase in intensity with a different laser?

Calibration system: *summary/conclusions*



- Continuing progress ...
- Nevertheless several ongoing studies ...
- Focus on few-tank **prototype array** is critical to help resolve the next set of issues ...