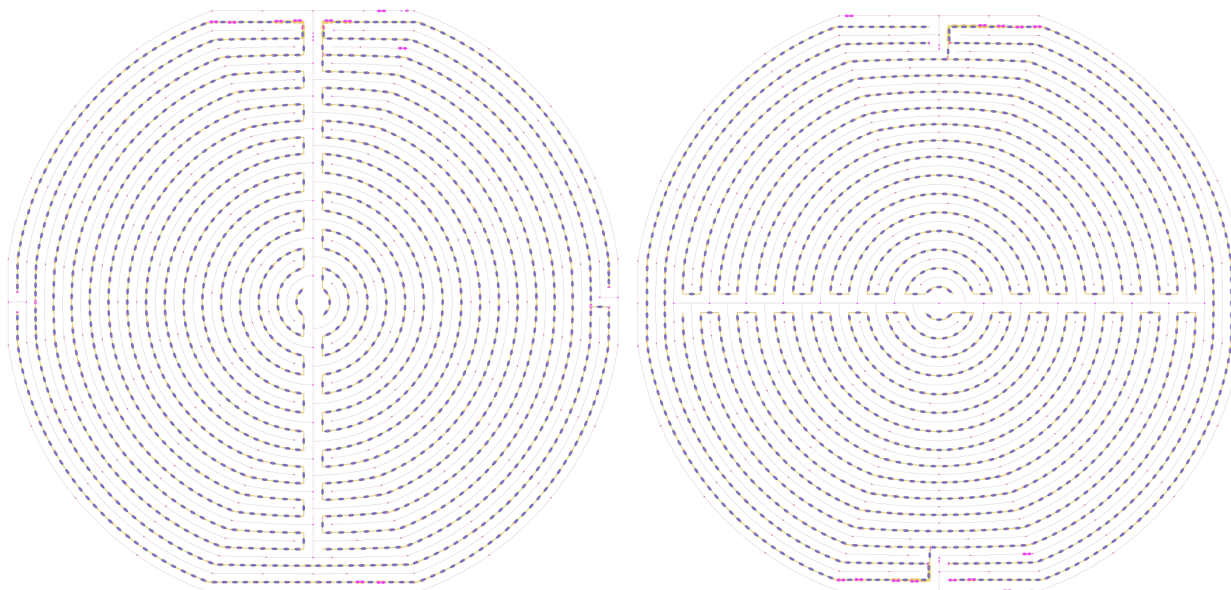




Stanford University



One Inch Thick SuperCDMS Detectors

FINAL TECHNICAL REPORT
for
**DUSEL RESEARCH AND DEVELOPMENT
ON SUB-KELVIN GERMANIUM DETECTORS
FOR TON SCALE DARK MATTER SEARCH**

Report No. DOE/ER41480-1

Grant DE-FG02-07ER41480
for the period
July 15, 2007 through July 14, 2011

Sept, 2012

- 1) Project title:
DUSEL Research and Development on Sub-Kelvin Germanium Detectors for Ton Scale Dark Matter Search
- 2) DOE grant number:
DE-FG02-07ER41480
- 3) PI's name, address, phone number and email address:
**Blas Cabrera
Department of Physics
382 Via Pueblo Mall
Stanford University
Stanford, CA 94305**
- 4) Period of time report covers:
July 15, 2007 to July 14, 2011
- 5) Amount of unexpended funds if any anticipated at the end of the current budget period. If the amount of unexpended funds exceeds 10% of the budget, explain on a separate page why these funds remain unexpended and how they will be used in the next budget period.
No unexpended funds by July 14, 2011.
- 6) Report. Do not exceed 5 pages per investigator (academic faculty). Short and concise is best. Give results of your work for the past year including publications, reports, talks, etc. in which group members made a significant contribution. Emphasize findings and their significance to the field. Give a brief description of work planned for the next budget period as well as present or anticipated problems. Do NOT include biographical sketches. This should all be in twelve point type or larger except for footnotes and DOE forms. Margins should be 2.5 cm.
Report attached in next section.
- 7) Number of FTE postdocs and graduate students directly supported by DOE funds.
1 graduate student
- 8) Other federal sources of support and amounts for faculty supported by this grant.
None - PI is supported on DOE base grant at 2 months of summer salary level.

Final Report for period July 15, 2007 to July 14, 2011

We have supported one graduate student and a small percentage of fabrication staff on \$135k per year for three years plus one no cost extension year on this DUSEL R&D grant. There were three themes within our research program: (1) how to improve the radial sensitivity for single sided phonon readout with four equal area sensors of which three form a central circle and fourth a surrounding ring; (2) how to instrument double sided phonon readouts which will give us better surface event rejection and increased fiducial volume for future CDMS style detectors; and (3) can we manufacture much larger Ge detectors using six inch diameter material which is not suitable for standard gamma ray spectroscopy.

With respect to (1), we demonstrated both with simulations and with the first few fabricated detectors the great advance produced by this simple reworking of the existing equal quadrant phonon sensor readout which we call mZIP. This successful demonstration has moved this design to the baseline for the two SuperTower project and the SuperCDMS Soudan project. We are now cooling down the first SuperTower at Soudan with five new detectors based on this tri-sensor plus outer ring design.

With respect to (2), we completed the fabrication of a Ge three inch diameter by one inch thick test device with a new symmetric phonon sensor design on both sides which we call iZIP. As shown on the front page of this report, this design interleaves the charge and phonon channels on both sides of the detector. This design was first demonstrated with a Si iZIP detector by CDMS [*Nucl. Instr. Meth. Phys.* **A559**, (2006) pp. 414-416 attached] and more recently a similar design with Ge was operated by EDELWEISS at their underground facility [<http://arxiv.org/abs/0905.0753>]. These successes have convinced us to build an improved iZIP design and compare its surface event rejection performance with the performance of our mZIP baseline design.

On both sides of this new iZIP design, the phonon sensors form the ground potential lines for the charge measurements, then on one side the charge lines are biased at +3 V and on the other side at -3 V. There are two charge amplifiers connected to each side for a total of four charge channels, with one on each side used as guard rings near the outer parts of the detector. In addition, there are three phonon channels on each side with the inner 80% of the area covered by two D-shaped sensors and an outer phonon sensor ring on each side. The opposite side the boundary between the D-shaped sensors is perpendicular to the one on the opposite side.

With this iZIP design, we reject surface events both with charge information and phonon information. For the charge signals, events more than 1 mm away from surfaces (>90% of volume) produce equal and opposite signals on the opposite face charge channels, whereas events within the 1 mm surface layer have asymmetric response with a larger signal on one face than the other. In addition, this design preserves much of the phonon timing information used by mZIP to identify surface events from rise time informa-

tion. We believe that the combination of both of these techniques will produce a larger rejection capability than using phonons alone.

This device was successfully tested at the UC Berkeley facility with our Stanford graduate student participating. We analyzed the excellent surface electron rejection performance when surface electron beta source (Cd-109) was placed over each face of the detector. This successful design has now been shown to provide the basis for a future ton scale experiment which may include teams from both the US and Europe.

With respect to (3), we made progress on the larger diameter detector R&D. After demonstrating excellent charge collection for a dislocation free Ge crystal, we ordered three inch diameter Ge crystals from Umicore in Belgium. They are the only company in the world to have production facilities for both ultra pure Ge crystals used for gamma ray spectroscopy and in another division larger diameter Ge crystal growth for infrared windows and photovoltaic cells. They agreed to obtain a quartz crucible capable of growing a six inch diameter crystal and initially grow three inch diameter crystals in that crucible. We did not receive these crystals in time for this R&D program.

Under future funding, after receiving these crystals, we would fabricate SuperCDMS three inch diameter mZIP detectors and characterize their performance at test facilities. Once we have demonstrated charge collection for a three inch crystal grown in this large crucible, we will order six inch diameter crystals and proceed to demonstrate charge collection in those. A two inch thick by six inch diameter Ge crystal has a mass approaching five kilograms, twenty times greater than our CDMS-II detectors which are one centimeter thick and three inches in diameter and eight times greater than our new SuperCDMS detectors which are one inch thick by three inches in diameter.