GlueX – Phase II Proposal
Revision 4.0, 16th December 2007

Background (Phase I):

The objective of Phase 1 was to demonstrate the feasibility of the SPM detector technology for BCAL. This Phase 1 of the project is now complete and both parties are convinced that the potential of the SPM has been sufficiently demonstrated to enter discussions on a Phase 2 Contract.

The proposed Phase 2 Contract (version 3.0) focused on fine tuning existing SPM cell performance based on the understanding of known SPM performance targets for this Phase II of the project, see GlueX-doc-795, June 20th 2007. In addition, a sufficient number of SPM tiles, 30 preproduction units would be supplied in this Phase to enable JLabs/UoR build early demonstrators. This was within a total budget set at $200K.

This proposal is a revision to Version 3.0 GlueX – Phase II Proposal in response to GlueX statement of work dated 12th December from Elton Smith, JLabs. The SOW outlines nominal design parameter targets for the SPM cells and tiles needed for Phase II together with tradeoffs in key parameter PDE and DC. In addition the requirement for a tiled 4x4 square and/or circular tile has also been specified.

The duration specified in this proposal will be maintained at 12months but there will be a significant escalation in activities and manpower needed and is reflected in the four strands identified in this program.

Note: All terms used in this proposal are yet to be agreed internally by GlueX consortium with SensL but at the time of writing this document the following convention is used.

SPM	*Silicon Photomultiplier*
Tile	*Silicon Photomultiplier tiled array of detectors e.g. square 4x4 array format or circular design.*
Microcell/Pixel	*Smallest unit cell in a SPM. This consists of a photon counting photodiode and a quenching resistor.*
Cell	*The cell is the smallest building block of an array. This is typically a 9mm^2 SPM array.*
Submodule	*Tile, Electronics and Housing to integrate to BCAL*

Phase 2 Proposed Project Structure

SensL's proposal is that the Phase 2 agreement between SensL and GlueX consists of a number of parallel developments and tasks associated. The developments termed strands have interdependencies and are structured as follows

- *Strand One "SPM Cell Performance":* To further develop the core SPM cell performance in line with PDE versus DC tradeoff. This will incorporate design & process development together with external techniques like cooling if deemed necessary to achieve performance targets
- *Strand Two "SPM Square tile":* To assemble preproduction units based on a 12x12mm^2 SPM tile using SensL's existing hybrid glass array assembly methods.
- *Strand Three "SPM Circular tile"*: To manufacture a circular prototype tiles by monolithic assembly methods.
- *Strand Four "Readout Electronics"*: Custom electronics to meet project goals.

Strand One "SPM Cell Performance"

Both Parties recognize that the target specified in the SOW document is continually evolving and will require updates during the course of Phase II as more is learned about the BCAL requirements, the capability of the SPM tile and trade-offs between parameters.

A Specification Change Process will therefore need to be agreed between the parties to handle parameter changes and the impact of same. The target specifications outlined in the SOW at present are the revision #2 to the design parameters. The key difference compared to GlueX-doc -795 has been the increase of PDE from >12% to 21% at 490nm while maintaining the PDE/DC performance curve outlined in the SOW. This requirement represents a significant change to the specifications which SensL understands is a result from a lower than predicted no. of photons delivered to the detector from the source. SensL are committed to working with GlueX to establish the link between simulations of the system and actual system measurements using SensL SPMArrays designed and manufactured for GlueX. To this end, SensL have proposed an increase in the quantity of devices to be supplied to GlueX for evaluation. In SensL's experience the quantities requested in the SOW are insufficient to allow proper detailed analysis and feedback from GlueX which SensL will use to improve the final deliverable.

Two approaches can be taken here for cell optimization and involve the following:

T1.1 PDE enhancements

Here SensL will consider methods to enhance the PDE of the device via design and/or process improvements. A review of the layout of the SPM cell will be carried out to see whether the fill factor can be improved.

- **Deliverable 1.1:** 50 SPM die packaged in T018 package with PDE enhancements.
- **Resources:** Mask set conditional upon review of design plus x2 process runs to optimize PDE performance.
- **Due Date:** Months 6

T1.2 DC reduction

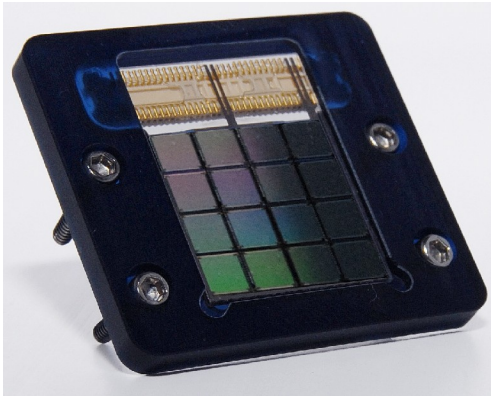
Two parallel methods are planned here. The first will involve continual process enhancement of the DC in line with developments during Phase I. This will require 3 further process iterations runs.

The second method will involve external cooling of the array in a suitable hermetic metal package using e-TEC's. Both techniques will be pursued and an assessment with regard to the DC performance and final production costing will be made at Month #9 in the project to determine which or both routes to continue pursuing.

- **Deliverable 1.2** Feasibility of 4x4 Tile with DC performance of 7.2MHz. This will be based on SensL supplying 32 SPM discrete packaged detectors in appropriated package such that DC performance per cell is 7.2MHz/16 = 0.45MHz.
- **Resources:** 3 full process runs for DC improvements plus NRE to develop the feasibility for cooling arrays for square and circular tiles.

Strand Two – "SPM Square tile"

Since October of this year, SensL has developed the following plastic housing with board to board connector. The module has been designed for summed and pixellated outputs.



SPMPlus GlassArray

Values	SPMArray (Module)	Units	Comments
Pixel Pitch	3.3	mm	Active area to active area
Glass Type	White Float glass, High Quality Thin Glass (Float Zone Glass)	-	-
Glass Thickness	550	µm	Typical Thickness
Glass Transparency	>90	%	-
Glass Plate Size	22 x 17	mm	-
Board to Board Connector	0.5mm Pitch Receptacle - SMT, Dual Row, Vertical Stacking (x70 pin)	%	See Schematics
Flip-Chip Underfill	Low Viscosity Optical Adhesive	-	-
Metal Tracks	CrNi -50nm, Ti -100nm, Au -2000nm	%	-
Metal Track Widths	Vary Between 150-300	µm	-
Housing	Plastic Housing	-	See Drawings

The glass module comes with a board-to-board connector. The connector details are 0.5mm pitch receptacle – SMT, Dual Row, Vertical Stacking (x70 pin) – Molex Part No: 53748 – 0700.

The compatible board connector for this units Molex 70 pin 52991 – 0708. The glass module specifications are as follows.

SensL will provide the project 30 packaged preproduction units for the project as originally agreed. However based on the needs to provide 2 package solutions 60 units in total will be delivered split equally between square and circular tiles.

The units based on square tiles to be delivered will be phased over two steps 1). to improve the uniformity issues identified by G Lolos, Nov. 19th 2007 in report titled *"Progress Report on the glass Mounted SPM Arrays"* and 2). to deliver the 30 preproduction units. While it is acknowledged at this point that uniformities issues have been identified it is not clear as to the source of problem and further work is therefore necessary to resolve and understand the problem and rectify. This will allow for determination as to the viability of the hybrid packaging approach for the final GlueX production units.

- **Deliverable 2.1** Deliver GlueX 30 preproduction units based on 4x4 square tile approach using hybrid assembly method demonstrated above. The preproduction units will be custom designed and will incorporate all the improvements available at Month #9 arising from Task 1.1 & Task 1.2.
- **Resources:** NRE cost: to engineer out the uniformity identified in the initial evaluation prototype units delivered to date.
- **Due Date:** Month 12

Strand Three "Circular Arrays"
This task will involve process iterations to determine the yield from a circular monolithic tile proposed in the SOW. Initial runs x2 will determine likely yields from this process and based on outcome a decision on whether to proceed with this route will be determined.

- **Deliverable 3.1** Deliver 30 prototype units based on a monolithic circular assembly. The prototype units will be custom designed and will incorporate all the improvements available at Month #9 arising from Task 1.1 & Task 1.2.
- **Budget:** NRE cost: for mask set for monolithic design plus 2 full process runs together with revision for assembly and housing for circular design and testing at SensL.
- **Due Date:** Month 12

Strand Four "Electronics"
This task will focus on developing the necessary custom electronics needed for readout and will incorporate pre-amplification with timing improvements plus, depending on the program, cooling driver electronics and on board power supply and distribution to the array.

- **Deliverable 4.1** Custom electronics for modules incorporating pre-amplification, cooling driver circuitry and power supply and biasing.
- **Budget:** NRE to custom design electronics.
- **Due Date:** Month 12

Budget Summary

The following table is a summary of the overall costs for the project based on a 12 month project duration. The project costs have increased to reflect the new level of engineering effort and cooperation with the GlueX team needed to commit to the target and goals specified in the SOW.

The additional costs are split according to tasks as follows between labor at 2½ man years for the duration of the project, engineering breakdown and overheads @20%. Overhead includes all testing, test equipment, facilities, project management, project support, plus all necessary overhead required to successfully implement the project. Labor costs are at a reduced rate to SensL standard rate to keep the project inline with previously discussed budgetary numbers.

Budgeted GlueX Phase II Proposal	PDE Performance	DC Perfromance	Square 4x4 Tile	Circular Tile	Electronics	
Project Cost Breakdown	**Task 1.1**	**Task 1.2**	**Task 2.1**	**Task 3.1**	**Task 4.1**	**Totals**
Total Labor	**40,000**	**40,000**	**40,000**	**40,000**	**40,000**	**200,000**
NRE		52,500	30,000	22,500	15,000	120,000
Travel & Subsistence	3,500	3,500	3,500	3,500	3,500	17,500
Mask Sets	15,000			15,000		30,000
Processing Costs	33,000	54,000		33,000		120,000
Preproduction Units	1,000	1,500	30,000	30,000	6,000	68,500
Electronics					35,000	35,000
Total Engineering	**52,500**	**111,500**	**63,500**	**104,000**	**59,500**	**391,000**
Overheads @20%	**10,500**	**22,300**	**12,700**	**20,800**	**11,900**	**78,200**
Total Project Costs	**63,000**	**133,800**	**76,200**	**124,800**	**71,400**	**469,200**

General Terms

- Price is in US$ and excludes: VAT, duty, taxes, bank fees, shipping fees and any other charges.
- FOB Cork, Ireland.
- Ship Via: DHL/UPS/FedEx
- Purchase Orders placed direct to SensL in Ireland
- Payment Conditions: 30 days net after date of invoice to our bank account.
- Quote Validity: 60 days from date of issue.
- Warranty: N/A, Engineering evaluation units only.

Payment Terms

The payment schedule will be as follows.

- NRE costs Up front – at the start of project
- Payment schedules 40% upfront, 40% upon delivery of sensors and 20% upon completion of satisfactory testing by GlueX.