1200-1800 nm
Semiconductor Laser Array

Presented to:
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Introduction

QPC Lasers, Inc. (www.QPClasers.com) is a world leader in the development and commercialization of high brightness, high power semiconductor lasers for the defense, homeland security, industrial, and medical markets. Founded in the year 2000, QPC is vertically integrated from epitaxy through packaging and performs all critical fabrication processes at its state-of-the-art high-technology semiconductor laser fabrication facility in the Los Angeles suburb of Sylmar, CA. QPC is ISO certified and holds 15 patents on semiconductor laser technology. QPC is a publicly traded U.S. company (NASD: QPCI).

This document describes the non-recurring engineering funding required for the development and delivery of 1200-1800nm Individually Addressable Internal Grating Stabilized High Power Single Mode Surface Emitting Semiconductor Laser Arrays, hereinafter called the “Product”.

Analysis of the blood glucose monitoring laser specification

QPC has considered the technical requirement for this blood glucose monitoring application. Several important technical requirements are noted:

1. Low cost, high volume architecture: The lowest cost structure and highest volume manufacturability is achieved with a single laser chip solution. QPC has patented the world’s only high power surface emitting laser array (HPSEL) which enables a revolutionary decrease in cost, size, and weight. Based on this semiconductor laser chip technology, QPC has won several competitive development contracts from the U.S. Navy and Department of Defense Advanced Research Projects Agency to develop laser chips for high energy weapons applications.
2. Narrow line width and precise control of center wavelength of each laser line: An internal grating is required since typical high power semiconductor lasers in the 1200-1800nm range emit light with 8-10nm linewidth. Achieving <2nm FWHM is only possible in a low cost application with an internal grating in the chip since external stabilization optics/gratings will add unnecessary cost, expensive high precision alignment, and reliability issues. QPC is the industry leader for Internal Grating technology and has developed lasers with Internal Gratings at 808, 976, 1470, 1532, and 1550 nm.
3. All emitters to focus to a 200um spot: This requirement is best met with single transverse mode performance. QPC has the highest power single mode 1550nm device which is also single frequency with narrow spectrum achieved with Internal Gratings.
4. Broad wavelength range at 1200-1800nm: This requires extensive experience in the Indium Phosphide semiconductor laser material system. QPC has excellent efficiency from conduction cooled linear arrays and has offered industry leading products in the 1300-1600nm regime with excellent reliability for the past several years.
5. Individual addressability of each emitter: QPC offers the 1550nm single mode single frequency laser product today with segmented emitters that enable independent driving of sections within the chip with small bond pads for high speed high power switching.

QPC's HPSEL, Internal Gratings, and BrightLase™ single mode laser technology

QPC has identified a low cost solution suitable for high volume production that meets the specification. The technology required is a QPC two dimensional high power surface emitting laser array with single mode emitters with internal grating.

As part of QPC's technology roadmap, QPC has previously developed and demonstrated the unique and proprietary semiconductor laser technologies which are required for the 1200-1800nm surface emitting semiconductor laser array. This NRE proposal describes the funding required to join the technologies which have demonstrated independently into a product. Specifically, QPC has demonstrated two types of devices which, when joined together, will meet the requirement for blood glucose monitoring laser array:

1. High Power Surface Emitting Lasers (HPSEL) with Internal Gratings: QPC has fabricated semiconductor laser array with >100 lasers on a single 2D chip that achieve narrow linewidth, precise emitter alignment for lensing, and low cost structure for high volume. This development effort was associated with a previously successful U.S. Navy contract where QPC demonstrated >300W 980nm Internal Grating Stabilized High Power Multi Mode Surface Emitting Semiconductor Laser Arrays with spectrum <1nm FWHM. The laser chip QPC developed is shown in Figures 1-3.
2. 1550nm BrightLase™ Single Mode Lasers with Internal Grating: QPC has fabricated high power >1W single mode single frequency emitters based on QPC's proprietary InP material system. This development effort was associated with a previously successful U.S. Missile Defense Agency contract where QPC demonstrated high spatial brightness and excellent spectral brightness and stability which allows the laser beams to be focused to a small spot with a precise and narrow wavelength emission. The devices are edge emitting semiconductor lasers with individually addressable sections within the chip that can be driven quickly (>GHz). The laser chip performance is shown in Figure 4.

The two previously demonstrated laser device technologies were the result of successful development programs. This proposal describes a product development effort that combines these elements above and extending the wavelength range.

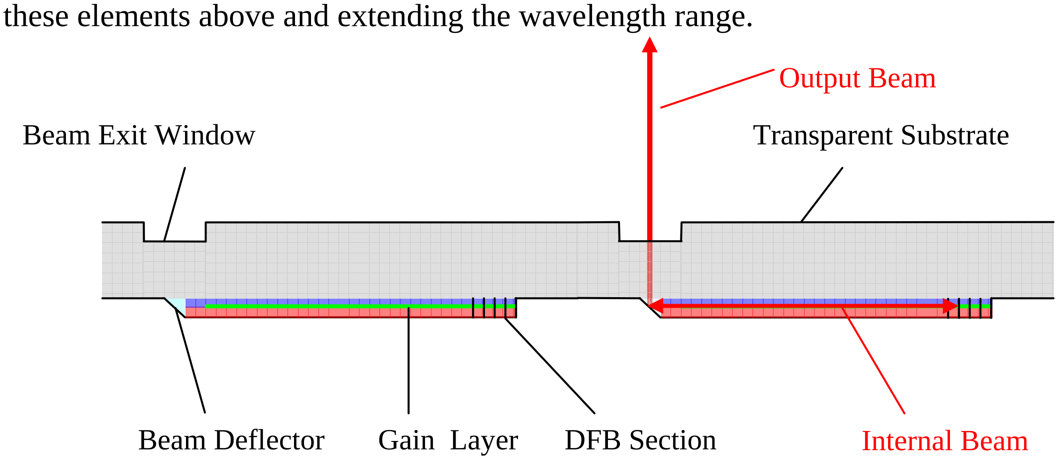

Figure 1: HPSEL device architecture

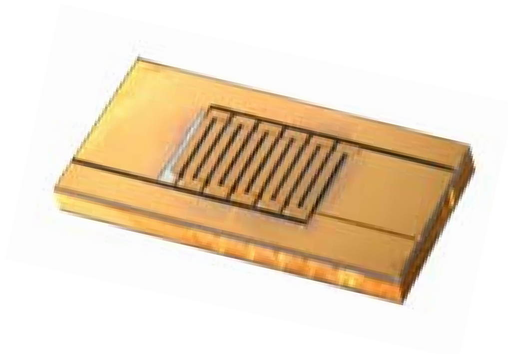

Figure 2: HPSEL device; roughly 1 cm x 1.5 cm

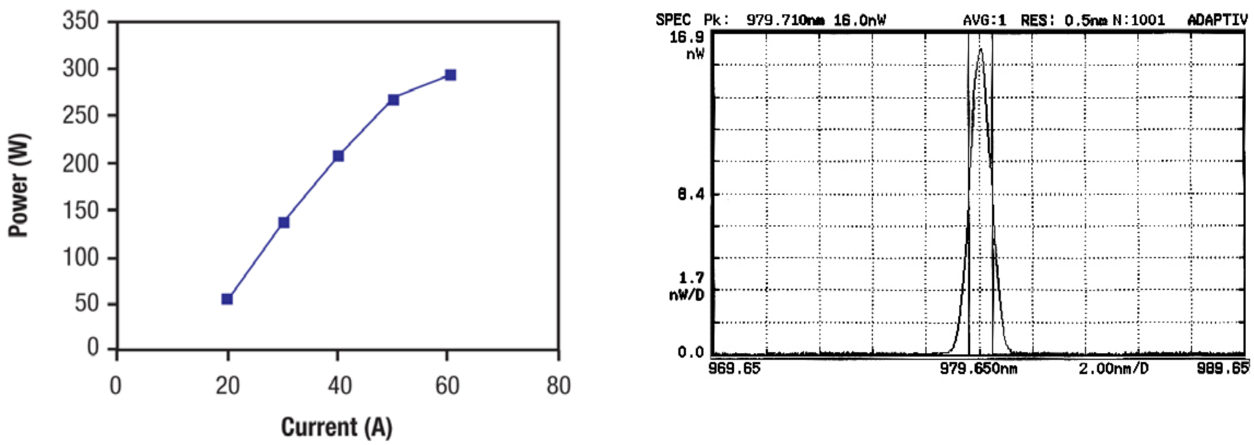

Figure 3: HPSEL device performance showing 300W at 980nm with spectrum <1nm FWHM.

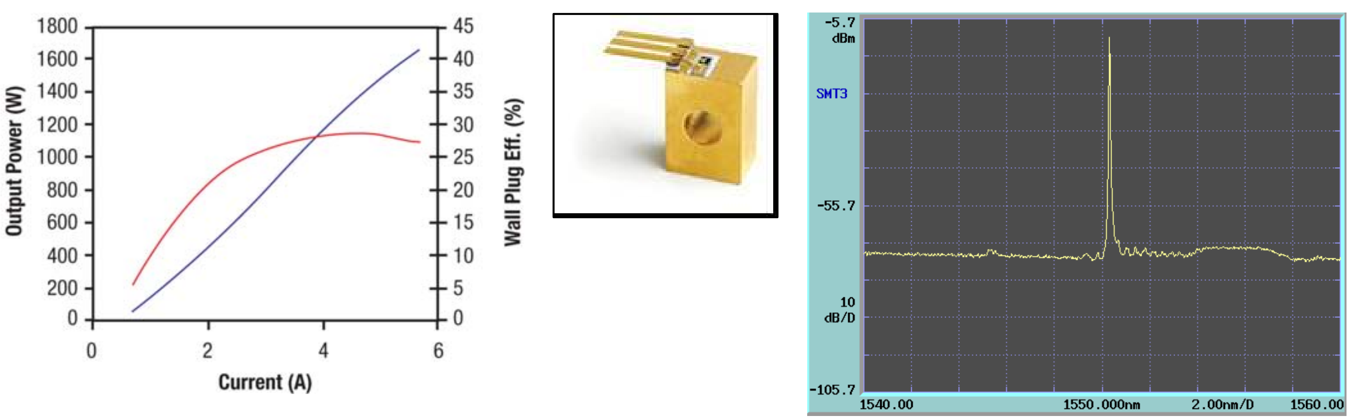

Figure 4: Single mode 1550nm edge emitting lasers showing >1W single frequency performance.

Advantages of QPC Semiconductor Lasers with Internal Gratings

QPC has demonstrated high power semiconductor lasers with internal gratings at 808 nm, 976 nm, 1470 nm, 1532 nm, and 1550 nm that narrow the linewidth, reduce the wavelength-temperature sensitivity, and ensure that the device operates at the desired center wavelength. Products are available at 808nm and 1550nm today, and other wavelengths and are available with NRE funding.

The performance of the InP semiconductor laser with an internal grating differs fundamentally from a conventional high power InP diode without the internal grating or from a conventional InP diode with an external grating. First, the ~ 1nm FWHM spectrum is significantly narrower than the 8-10 nm FWHM typically achieved in conventional high power diode lasers without a grating.

Another major difference between devices with an internal grating and conventional diode lasers is the lower wavelength – temperature coefficient. For conventional laser diodes, this coefficient is 0.35nm/ºC while for devices with internal gratings, it is 0.15nm/ºC. This reduction in temperature sensitivity relaxes the requirement for thermal stabilization, enabling systems with reduced size and weight.

A third major difference is the significantly improved center wavelength accuracy achieved in the manufacturing process. Conventional laser diodes are provided with a +/- 10nm center wavelength tolerance due to growth control and uniformity factors. On the other hand, the wavelength of devices with internal gratings is determined by the period of the grating which can be controlled accurately and is not affected by growth uniformity. This enables a +/- 1.0nm spread in devices from growth to growth, and wafer to wafer.

QPC internal grating approach offers high spectral brightness and stability in a robust design. The QPC internal grating approach offers several advantages over external grating approaches:

- QPC internal gratings eliminate the need for costly external optical stabilization elements and their associated costly high precision alignment
- QPC internal gratings offer a broad and robust temperature locking range as compared with the narrow temperature range of performance associated with external optical stabilization
- QPC internal gratings eliminate the failure mechanisms associated with external optical stabilization; even modest misalignment of an external grating may lead to device failure
- QPC internal gratings device performance is insensitive to bar smile and micro-optic alignment; devices built with external gratings are quite sensitive to drift of the micro-lens, changes in the grating alignment, and any changes in the bar smile which may be induced by environmental changes over the life of the product
- QPC internal gratings eliminate the additional noise in both power and spectrum that associated with external optical stabilization techniques which exhibit time dependent noise associated with the mechanical instability of the external elements

Product Specification

The development of the Product is segmented into 2 Milestones (3 month sub-milestone intervals).

Milestone 1a (9 weeks ARO)

The deliverables of this milestone are two (2) fiber coupled devices that feature edge emitting internal gratings. The devices will be delivered at 1550nm and 1565nm. Photoluminescence data will also be provide for the wafers covering all wavelengths.

Milestone 1b (12 weeks after Milestone 1a)

The deliverables of this milestone are fiber coupled devices that feature edge emitting internal gratings. 128 devices will be provided at 5nm spacing based on the following delivery schedule:

- 30 devices end of week 18
- 30 devices end of week 19
- 30 devices end of week 20
- 38 devices end of week 21

The devices will be packaged in a butterfly housing with the following geometry:

Each device will have the following specifications:

PARAMETER	QPC Specification
Power	25mW minimum
Wavelength	1200, 1205, 1210, … 1850, 1855, 1860nm
Pulse length/Duty cycle	Up to 10mS pulse length, 4% duty cycle
Wavelength Tolerance	± 1.5nm
Spectral Width (FWHM)	≤ 2nm
Operating Current	≤ 2A
Operating Voltage per emitter	≤2V
Temperature tuning coefficient	<0.15 nm/°C
Operating conditions	20^{O}C
Fiber diameter	50 micron core or less
Rise time	<50 ns per element

Milestone 1 Pricing: NRE: $1,800,000

Milestone 1 Delivery Schedule for Deliverables:

- Phase 1 Project Initiation Report: This will be attached to the order acknowledgement and summarizes the key project elements such as design, documentation, fabrication, testing.
- Monthly Development Reports: Last day of each month
- Delivery for Devices: 6 months ARO

Milestone 1 Payment Terms:

Phase 1 Project Initiation	$130k Net 30 days after receipt invoice	$128k Net 180 days after receipt invoice
Month 1 Deliverable	$129k Net 30 days after receipt invoice	$128k Net 150 days after receipt invoice
Month 2 Deliverable	$129k Net 30 days after receipt invoice	$128k Net 120 days after receipt invoice
Month 3 Deliverable	$129k Net 30 days after receipt invoice	$128k Net 90 days after receipt invoice
Month 4 Deliverable	$129k Net 30 days after receipt invoice	$128k Net 60 days after receipt invoice
Month 5 Deliverable	$129k Net 30 days after receipt invoice	$128k Net 30 days after receipt invoice
Month 6 Deliverable	$129k Net 30 days after receipt invoice	$128k Net 30 days after receipt invoice

<u>Milestone 2a (12 weeks after milestone 1b)</u>

The deliverables in this milestone will be a meeting to discuss the resulting tests performed by Dominion, LLC. resulting from milestone 1a and 1b deliverables and to review the progress being made for the final edge or surface emitting arrays with internal gratings to be delivered at the completion of this agreement. One (1) prototype partial array with 20 wavelengths from milestone 1a (within 1465nm to 1610nm) for testing and confirming the initial mechanical and electrical approach by Dominion.

<u>Milestone 2b (12 weeks after milestone 2a)</u>

The deliverables in this milestone feature edge or surface emitting arrays with internal gratings. Each element is individually addressable over a 1200-1860nm wavelength range. Three (3) prototypes of 20 x 7 arrays will be delivered based on the wavelength versus power spreadsheet (Attachment A). Additional prototypes will be available at $10,000.00 each (1-9 pieces).
Each emitter will have the following specifications:

PARAMETER	QPC Specification
Spatial mode	DBR 100 micron emitters
Power	25mW minimum
Pulse length/Duty cycle	Up to 10mS pulse length, 4% duty cycle
Wavelength Tolerance	± 1.5nm
Spectral Width (FWHM)	≤ 2nm
Operating Current	≤ 2A
Operating Voltage	≤2V
Temperature tuning coefficient	<0.15 nm/°C
Package type	Roughly 1cm x 1.5cm
Operating conditions	20^{O}C
Rise time	<50 ns per element
Optical power variance	< 5% (<.1% preferred) per element (repeatability)
Warm up time to stability	< 30 s
Max optical power variance	< 50% between elements if 300mW not achievable on all elements (min power per element is 25mW)
Addressability	Each element, firing sequence not successive with wavelength

Milestone 2 Pricing

- NRE: $1,000,000
- NRE for Microlens array option to collimate the emitters: $250,000

Milestone 2 Delivery Schedule for Deliverables:

- Monthly Development Reports: Last day of each month
- Prototypes: 6 months after completion of Milestone 1

Milestone 2 Payment Terms:

Month 7 Deliverable	$209k Net 30 days after receipt invoice
Month 8 Deliverable	$209k Net 30 days after receipt invoice
Month 9 Deliverable	$208k Net 30 days after receipt invoice
Month 10 Deliverable	$208k Net 30 days after receipt invoice
Month 11 Deliverable	$208k Net 30 days after receipt invoice
Month 12 Deliverable	$208k Net 30 days after receipt invoice

Other terms and conditions:

- Other terms and conditions shall be as per QPC's standard terms and conditions.
- This proposal shall be valid for 90 calendar days from February 1, 2008.

Point of Contact

All communication relative to this proposal should be directed to:

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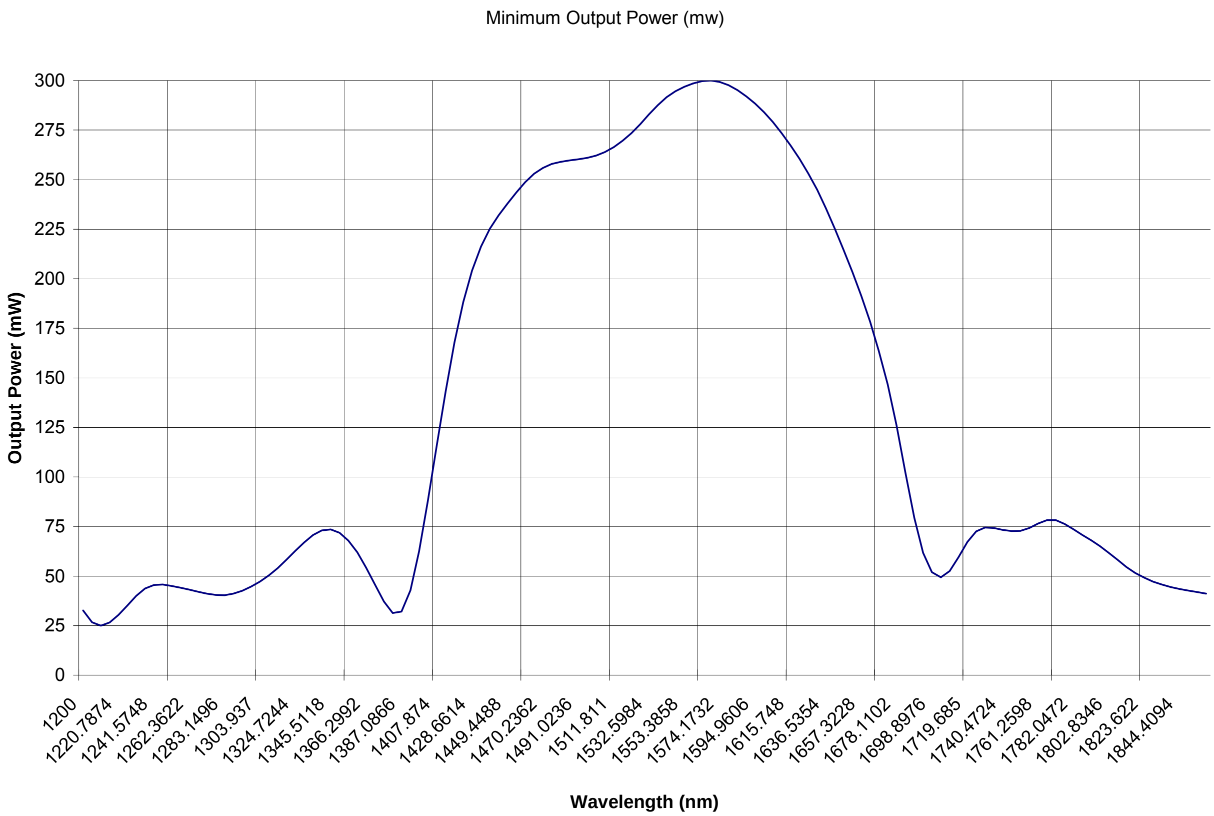
Attachment A

Wavelength (nm)	Minimum Output Power (mw)	Wavelength (nm)	Minimum Output Power (mw)
1200	33	1533	283
1205	27	1538	288
1210	25	1543	292
1216	27	1548	295
1221	30	1553	297
1227	35	1559	299
1231	40	1564	300
1236	44	1569	300
1242	45	1574	299
1247	46	1579	298
1252	45	1585	295
1257	44	1590	292
1262	43	1595	288
1268	42	1600	284
1273	41	1605	279
1278	40	1611	273
1283	40	1616	267
1288	41	1621	261
1294	43	1626	253
1299	45	1631	245
1304	47	1637	236
1309	50	1642	225
1314	54	1647	215
1320	58	1652	203
1325	63	1657	191
1330	67	1663	178
1335	71	1668	164
1340	73	1673	147
1346	73	1678	126
1351	72	1683	102
1356	68	1689	79
1361	62	1694	62
1366	54	1699	52
1371	46	1704	49
1377	37	1709	53
1382	31	1714	59
1387	32	1720	67
1392	43	1725	73
1397	63	1730	75
1403	88	1735	74
1408	116	1740	73
1413	143	1746	73
1418	168	1751	73
1423	188	1756	74
1429	204	1761	76
1434	216	1766	78
1439	225	1772	78
1444	232	1777	76
1449	238	1782	74
1455	244	1787	71
1460	249	1792	68
1465	253	1798	65
1470	256	1803	62
1475	258	1808	58
1481	259	1813	55
1486	260	1818	52
1491	260	1824	49
1496	261	1829	47
1501	262	1834	46
1507	264	1839	44
1512	266	1844	43
1517	270	1850	43
1522	273	1855	42
1527	278	1860	41

Wavelength and Power Spreadsheet


Minimum Output Power (mw)
Output Power (mW)
300
275
250
225
200
175
150
125
100
75
50
25
0
1200
1220.7874
1241.5748
1262.3622
1283.1496
1303.937
1324.7244
1345.5118
1366.2992
1387.0866
1407.874
1428.6614
1449.4488
1470.2362
1491.0236
1511.811
1532.5984
1553.3858
1574.1732
1594.9606
1615.748
1636.5354
1657.3228
1678.1102
1698.8976
1719.685
1740.4724
1761.2598
1782.0472
1802.8346
1823.622
1844.4094
Wavelength (nm)