NRL BAA Announcement
#68-15-01

RF VACUUM ELECTRONICS

The Vacuum Electronics Branch of the Naval Research Laboratory (NRL) is seeking proposals for innovative technology base development in the broad area of vacuum electronics. Areas of interest include, but are not limited to: (1) advanced high power microwave and millimeter-wave amplifiers suitable for applications in radar, electronic warfare, high data rate communications, imaging, and remote sensing; (2) microwave or millimeter-wave power modules (MPM) consisting of a solid-state driver, a vacuum electronics power booster, and integrated power conditioning; (3) manufacturing technologies and techniques to enable the high yield fabrication of precision vacuum electronic components and assemblies suitable for operation above 20 GHz while reducing life cycle costs and improving overall device reliability; (4) theory and design tool development to support an advanced computational environment for the computer-aided design of vacuum electronic devices operating from microwave to terahertz frequencies; (5) supporting technology to advance RF vacuum electronics; (6) advanced emitter technology; and (7) amplifiers or oscillators driven by spatially-distribution electron beams . Each area is briefly described below:

(1) High power microwave, millimeter-wave, and sub-millimeter-wave amplifiers. The overall goal of this program area is to develop the technology base required for advanced high performance microwave, millimeter-wave, and sub-millimeter-wave amplifiers suitable for radar, communications, electronic warfare, imaging, and remote sensing applications. Proposals are encouraged detailing device concepts relating to the development of compact, efficient vacuum electronic amplifiers operating in the microwave (1-30 GHz), millimeter-wave (30-300 GHz) and sub-millimeter-wave (300 GHz – 1 THz) bands, with peak power levels ranging from milliwatts to megawatts, and average power levels of milliwatts to tens of kilowatts or higher, depending on the operating frequency and application. Devices should be capable of operation with instantaneous fractional bandwidths of 1% to 20% or higher. Topics of interest include, but are not limited to innovative high power device concepts using both slow-wave and fast-wave approaches and advanced high-power electron optics and component technology.

(2) Microwave and millimeter-wave power modules, consisting of a solid-state driver, a vacuum electronics power booster, and integrated power conditioning, will find applications in many military and civil systems, including electronic decoys, phased

arrays, and high-data-rate communications. Proposals are encouraged under this solicitation that address topics such as (a) improved magnetics to provide high- quality high-perveance electron beams within module cross-section and weight constraints; (b) improved beam-wave interactions and depressed-collector designs to enhance power booster efficiencies; (c) innovative waste heat removal designs for a dimensionally-constrained MPM; (d) improved solid-state amplifier performance at high-junction temperatures; (e) novel power conditioning schemes to provide spectral purity for radar applications; (f) development of low-loss passive components and devices to minimize overall system losses; (g) improved power conditioning components such as high voltage diodes and capacitors suitable for high-density power conversion; (h) three-dimensional fully-electromagnetic computer modeling; (i) innovative approaches to developing MPM architectures leading to low unit acquisition costs; and (j) innovative power extraction schemes capable of providing small cross-sectional power modules for m x n array applications.

(3) The advanced manufacturing technology program area includes but is not limited to the development of innovative fabrication techniques such as microfabrication, 3D printing, and other additive manufacturing concepts that can improve the performance and fabrication yield of vacuum electronic devices, particularly in the millimeter-wave to sub-millimeter-wave operating regimes. This program area also seeks innovative concepts for fabrication in which critical design elements are identified and novel solutions are offered in order to minimize cost, supported with manufacturing analysis as evidence. DoD microwave power tube procurements have traditionally been low-volume runs of limited duration; production of power tubes for certain high-volume applications, such as decoys, is currently too costly. Proposals detailing concepts consistent with these area objectives that are aimed at decoupling unit cost from production volume are encouraged under this solicitation.

(4) The physics-based computer-aided design (CAD) program area is focused on the development of advanced theory, design, and simulation capabilities related to vacuum electronic devices. This task seeks the development of accurate physics-based models that can be implemented in computationally-efficient algorithms and integrated into state-of-the-art computational design codes. The numerical tools should address electromagnetic, electron beam–electromagnetic wave interaction, and thermal and mechanical issues associated with vacuum electronic devices. The development of both general electromagnetic and device-specific vacuum electronic computational tools is sought. The design tools can use steady state or time-dependent models focusing on one-dimensional, two-dimensional or three-dimensional aspects of the problem. In concert, within the design methodology framework, the design tools should be capable of optimizing the performance of the device by maximizing, for example, the efficiency, gain, linearity, and bandwidth and minimizing the noise. Code validation through comparison with experiment and/or the predictions of other computational tools is desired. Theory and computational tools to study the propagation of electromagnetic waves in free space and to investigate the interaction of electromagnetic fields with other materials and/or three-dimensional structures are also of interest.

(5) The supporting technology program area encompasses the development of materials and technologies that can potentially benefit broad classes of vacuum power amplifiers and oscillators. Proposals that detail innovations and breakthroughs in any one of a variety of technical areas in this context are encouraged. Technical areas include, but are not limited to: (a) innovative cooling techniques for both vacuum and solid state devices; (b) innovative materials research for vacuum power devices, including mechanical and electromagnetic characterization, modeling, and development of materials, such as high thermal conductivity insulators, BeO replacement materials, and materials with tailored electromagnetic losses; (c) metamaterials; (d) passive components such as filters, combiners, quasi-optical components, and control components such as phase shifters; (e) novel compact sources to provide power and power conditioning for vacuum electronic devices; and (f) mass- and volume-efficient magnetic materials and magnetic structures to support compact, fieldable systems.

(6) The advanced emitter technology program area covers both established and evolving electron sources relevant to RF vacuum electronic devices. In most cases high current density, long lifetime, and superior robustness are desired. In specific situations cathodes compatible with insertion into meso-scale and micro-scale electron devices are required. Cathodes suitable for multiple beam and sheet beam devices are of particular interest. Proposals include but are not limited to the following areas: (a) thermionic sources including improved work function-reducing mechanisms allowing longer lifetime and improved uniformity; (b) field emitter arrays including means of regulating the emission at individual sites, means of scaling the total emission current with area, and having moderate to high current density; (c) explosive emission cathodes; (d) plasma cathodes and beam-plasma interaction; (e) semiconductor materials having properties suitable for creating sources requiring low or negative electron affinity; (f) materials and systems required for photoemitters; (g) cathodes and secondary emitter materials; (h) improved collector design and materials, including methods to suppress secondary electron emission; and (i) related theory and computational modeling. Proposals that detail breakthroughs and innovations in the materials development and/or cathode design in any of the above areas are encouraged.

(7) Amplifiers driven by spatially-distributed electron beams. The overall goal of this activity is to develop the technology base required for spatially-distributed electron beam high-performance amplifiers suitable for DON/DoD applications. Proposals detailing device concepts relating to the development of compact, lightweight, low noise, efficient vacuum electronic amplifiers operating in the range of frequencies from 1 GHz to 1 terahertz at peak power levels from milliwatts to hundreds of kilowatts, and average power levels of milliwatts to tens of kilowatts. Devices should be capable of operation with fractional instantaneous bandwidths of 1% to 20% or higher. Topics of interest include, but are not limited to, (a) innovative high power device concepts; (b) advanced high-power electron optics for the electron guns and/or multistage depressed collectors; (c) innovative high current density cathodes for long life; (d) design methodology for low manufacturing cost; (e) multi-stage depressed collector design; and (f) novel concepts for electron beam confinement and transport.

Address White Papers (WP) to VE_NRL_BAA@nrl.navy.mil. Allow one month before requesting confirmation of receipt of WP, if confirmation is desired. Substantive contact should not take place prior to evaluation of a WP by NRL. If necessary, NRL will initiate substantive contact.