

*Space Technology and Applications International Forum (STAIF-2004),  
Albuquerque, New Mexico, February 8-12, 2004*

## **Precursor Proof-of-Concept Experiments for Various Categories of High-Frequency Gravitational Wave (HFGW) Generators**

Robert M. L. Baker, Jr.

*Senior Consultant, GRAVWAVE® LLC and Transportation Sciences Corporation, 8123 Tuscany Avenue  
Playa del Rey, California 90293, USA, Telephone (310) 823-4143, Fax (310) 821-1694, E-mail  
[robert.baker.jr@comcast.net](mailto:robert.baker.jr@comcast.net)*

**Abstract.** High-Frequency Gravitational Wave (HFGW) generators are separated into three general categories. Precursor, component-validation, laboratory experiments for each category except, possibly, the third are identified in general terms. The categories are:

- The electromechanical category includes micro- and nano-element, piezoelectric crystal, and multi-dielectric film HFGW generators.
- The high-temperature superconductor category includes *gasers*, impressed magnetic fields, and transformation of electromagnetic radiation into gravitational waves (Gertsenshtein effect) HFGW generators.
- The laser/plasma category includes laser-energized mirrors, synchrotron light, nuclear fusion, plasma toroid, and nonlinear optical-acoustical, molecular-level HFGW generators.

A perusal of HFGW literature reveals that since the 1960s many authors have contributed designs of mechanisms and devices that relate to the terrestrial generation of gravitational waves. Only in the last few years, however, have any researchers demonstrated that their proposed devices were practical HFGW generators, capable of producing kilowatts of power, that were operational in a laboratory setting. These recent devices make use of new technology and generate high-frequency (GHz and above) gravitational waves using non-gravitational forces. Most of the generators considered in this paper have been recently discussed at the May, 2003, *Gravitational Wave Conference* at The MITRE Corporation, McLean, VA, which was the very first International Conference dedicated to HFGW and attracted twenty-five research papers from nine countries. Although no detailed experimental tasks are discussed, experimental test objectives in the form of a roadmap are proposed for each category.

### **INTRODUCTION**

There exist three general categories of High-Frequency Gravitational Wave (HFGW) generators: electromechanical, high-temperature superconductor, and laser/plasma. We will not consider the very low-frequency (down to mHz) gravitational waves generated celestially by gravitational forces of interest to astrophysicists, which relate to a totally different technology (HFGW technology is different from that utilized in LIGO, GEO6000, VIRGO, *et al*). For each of the devices comprising these general categories there is a precursor experimental protocol that is generally described herein and is useful for experimental planning. By “precursor” I mean experimental tasks that are predecessors to the test of the capability of devices in question to actually generate detectable HFGW in the laboratory. These are component-

validation, laboratory experiments. As an example of a precursor experiment, let us consider the micro- and nano-element devices included in the first electromechanical, HFGW-generator category. The concept of these devices is to impart a large jerk to a mass or system of masses and thereby generate significant HFGW. In this case the actual devices involve a myriad of energizing and energizable elements. Precursor experimental tasks would involve testing the efficacy of a single element or mechanism. That is, to measure the jerk produced in one single energizable element (in this case a small permanent magnet). If the jerk is successfully produced, then the mechanism can be replicated. Those replicated mechanisms, when controlled by a computer logic system, can be utilized as micro- or nano-elements in these devices, which are now capable of generating *many kilowatts* of HFGW in the laboratory.

This paper includes sections that are devoted to each of the three categories of HFGW generators. These sections then reference the specific research efforts involved in the particular category and explain the device's approach in each of the categories for HFGW generation in general terms. Most of the generators considered in this paper have been recently discussed at the May, 2003, *Gravitational Wave Conference* at The MITRE Corporation, McLean VA 22102, USA which was the very first International Conference dedicated to HFGW and attracted twenty-five researchers from nine countries. Various precursor experiments (the experiment list is not intended to be comprehensive) are quite generally described as a guide to the device's development process.

## ELECTROMECHANICAL HFGW GENERATORS

The precursor experimental tasks for the micro- and nano-device **electromechanical** HFGW generators (please see Baker, 2000a, 2000b, and 2003 for a description of a *three hundred and eighty kilowatt* HFGW generator) in this category the tasks have been discussed in the foregoing and in Baker (2004). In a little more detail regarding them, it is necessary to test the ability to produce very short (e.g., picosecond or less duration) energizing pulses (e.g., current, electromagnetic, laser, etc.). Next the ability of various sensing or measuring instruments (e.g., strain gages, Doppler laser, interferometers, piezoelectric crystals, etc.) to measure the energizable element's jerk must be tested in order to calibrate such an experiment.

With regard to the utilization of an array of piezoelectric **electromechanical** crystals for HFGW generation, the recent paper by Dehnen and Romero-Borja (2003) describes such devices best. The concept here (as originally suggested by Weber, 1960) is to stress the crystals at high frequency (THz or higher) by means of electrical pulses and utilize the resulting vibration, oscillation or jerk (contractions and expansions of the crystals) to generate HFGW. An array of such crystals is connected to a computer logic system required to energize each crystal as the HFGW wave front passes and generates a coherent and needle-like, super-radiant beam of HFGW. At least two precursor experimental tasks would be of value here. First, the response of a piezoelectric crystal of various sizes and shapes to high-frequency pulses should be measured. Second, a single row of crystal vibrators, which are elements of the chain of such rows comprising the device, should be fabricated and tested at high frequency and the motion and internal strain characteristics of the piezoelectric crystals studied.

As indicated by Portilla and Lapiedra (2001), "An electric charge shaken (or jerked) in a homogeneous stationary magnetic field produces both electromagnetic and gravitational waves (Gertsenshtein waves)." In addition Portilla (2003) suggested that such a device could be "...utilized to construct a (**electromechanical**) generator of HFGW and ... by connecting the generator elements to a computer controlled logic system our device could be incorporated in a communications system." The latest publication (Navarro, Portilla, and Valdes, 2004), suggests a test of such a concept through use of an electron paramagnetic resonant spectrometer. Precursor tests of the strong magnetic field, vacuum chamber, and microwave generator are also in order. The sensitivity of their antenna should be studied. Finally, several configurations of a wave-guide contained multi-dielectric film should be tested.

In summary, the precursor experiments that are, in general, generic to this category are elucidated in Baker (2004) and Navarro, Portilla, and Valdes (2004).

## HIGH-TEMPERATURE SUPERCONDUCTOR HFGW GENERATORS

The HFGW generator equivalent of the laser, the *gaser*, was originally proposed by Halpern and Laurent (1968), again suggested by Fontana (1998), and then presented in more detail by Fontana and Baker (2003). In this latter article they adopted a combination of three theories on gravitational-wave emission at the quantum level (the jerk) to show that their approach can offer the required smallness of the transition line-width and the required increase of the emission probability. In their *gaser* concept, coherence would be provided by the collective wave-function of Cooper pairs in a **high-temperature superconductor** (HTSC) to generate high-frequency gravitational waves (HFGW). They calculated the output power of the HFGW (*ten megawatts* at 1.3 THz) and also proposed a configuration capable of producing a focused beam of radiation of HFGW. The focus can be dynamically adjusted by "...a mechanical connection of the generator elements to a computer controlled logic system." Fontana (2004) suggests a test methodology that would involve precursor tests of the electric current source, the *gaser* material, and the HTSC.

Ning Li (2003) looked at a curved space and at the gravitational scalar and vector potentials. The scalar potential is ignored because it is too difficult to deal with. When Li completes her algebra, it appears that **high-temperature superconductors** (HTSC), by virtue of the jerk of the Cooper-pair electrons, can generate *eleven kilowatts* of gravitational-wave power under an impressed magnetic field controlled by a computer logic system similar to the concept of Fang-Yu Li, Tang, and Shi (2003). Precursor experiments would involve the test of an alternating (AC) magnetic field: its intensity, its highest frequency and variation of strength, and the ability to fabricate a YBCO HTSC of sufficient size to generate the HFGW.

Chiao (2002) describes an experiment in which he plans to convert electromagnetic (EM) waves into HFGW (Gertsenshtein effect) inside a device that is poised to go from a normally conducting state to a superconducting state. Specifically, "...that Type II **high-temperature superconductors** (such as YBCO) are considered to be macroscopic quantum gravitational antennas, which can simultaneously also be used as efficient transducers (by jerking electrons) for converting EM into HFGW, and vice versa." Precursor experiments would involve activating and testing the EM generator to define its characteristics and testing various designs of the YBCO HTSC.

In summary, the precursor experiments that are, in general, generic to this category are elucidated in Fontana (2004) and Chiao (2002).

## LASER/PLASMA HFGW GENERATORS

Baker (2004) describes the use of a pulsed **laser** beam (very short, e.g., femtosecond or attosecond, pulses at high repetition frequencies, e.g., MHz and higher) that produce jerks in a target-mirror energizable element (Baker 2000b) and about *six kilowatts* of HFGW power. The precursor tests involve the generation of the pulses and the tests of various target mirrors as discussed in more detail in Baker (2004).

Rudenko (2003) suggests that for HFGW generation one should utilize strong non-gravitational forces: possibly those that exist within a HTSC, or a large array of micro-electromechanical devices, or large numbers of coherently excited nano-piezoelectric crystals, etc., or "...to keep the resonance condition (i.e., maximum vibration or jerk amplitude) one has to decrease the mass (scale) of elementary radiator taking into account a possibility of using a natural mass-quadrupole at the molecular level. The deficit of mass in this case might be covered by increasing the total number of coherent micro radiators and detectors  $N_r, N_d$ . It is obvious the maximum density of cells can not exceed the value  $A=10^{22} - 10^{24}$  per  $cm^3$ . After this argumentation it is reasonable to seek a solution of the problem of effective GW generation by means of collective excitation of molecular oscillations at optical frequencies taking place in a nonlinear optic-acoustical media. One has to choose a molecular with largest quadrupole moment; an instrument for their excitation might be a powerful optical **laser** beam; a coupling of optical, acoustical and gravitational waves must be provided by nonlinear optical permeability of the media. Accumulation of the

GW power as well as its beaming might be provided by the synchronism conditions typical for interaction of waves traveling through nonlinear optical media.” Rudenko concludes that traveling electromagnetic (please see also Grishchuk, 2003, in this same regard) and acoustic (quadrupole) waves interacting (jerking) in nonlinear medium looks quite reasonable and promising at the range of optical frequencies,  $(10^{14} - 10^{15})Hz$ , for the generation of HFGW. Precursor experiments would include tests of powerful laser beams, of nonlinear optical permeable materials, and traveling EM waves.

Stephenson (2003) suggests the use of strong synchrotron light in a strong magnetic field to generate HFGW via the Gertsenshtein effect. The quadrupole (jerk) modulation of a synchrotron light source (SLS) and a low-hysteresis target for light generation are proposed. The precursor experiments would include test of various SLS and target designs. Stephenson also suggests a **plasma** toroid approach using plasma modulation to couple quadrupolar energy flow for HFGW generation. Precursor experiments would involve tests of various mass/plasma designs, confinement designs (e.g., tokomak), and tests of modulation equipment.

Nuclear fusion generation of gravitational waves was originally studied by Chapline, Nuckolls, and Woods (1974). More recently Rudenko suggested "...**laser** stimulated thermo nuclear fusion or laser micro-target explosions look more promising for the laboratory generation of HFGW." It is difficult to suggest precursor experiments here due to the safety concerns with nuclear reactions; however scientists at, for example, the *Lawrence Livermore National Laboratory* or similar nuclear research facilities in Russia or China might have some suggestions.

This third category of HFGW generators is the least mature of the group and may not be ready for component-validation laboratory experiments. It is, therefore, difficult to establish generic guidelines for precursor experiments. As Paul Murad has suggested (May 8, 2003) one might consider "... using a laser (energizing element) to radiate a gas such that shock waves are formed to create a pressure pulse that induces a particle (energizable element) jerk." Measurement of such an imbedded particle (or gas molecule) jerk might reveal the capability of such a process, with greatly increased power, to generate HFGW.

## CONCLUSIONS

It is self evident from the research efforts cited in this paper that significant theoretical analysis has been devoted of late to the laboratory or terrestrial generation of HFGW. Now is the time to supplement these studies with a series of precursor experiments. Experiments that will incrementally lead to the fabrication and test of one or more HFGW generators and the detection of their emanations by the HFGW detectors that have already been fabricated in England (please see Cruise, 2000), Italy (please see Chincarini and Gemme, 2003) and China (please see Li, Tang, and Shi, 2003). **The time is right, *carpe diem* ... seize the moment!**

## ACKNOWLEDGMENT

I wish to express my great appreciation to Paul Murad for his editorial and substantive contributions to this paper.

## REFERENCES

- Baker, R. M. L., Jr., "Gravitational Wave Generator," *United States Patent 6,417,597*, 50 claims, filed July 14, 2000a.
- Baker, R. M. L., Jr., "Gravitational Wave Generator Utilizing Submicroscopic Energizable Elements," *United States Patent Application 09/752,975*, 100 claims, filed December 27, 2000b.
- Baker, R. M. L., Jr., "Generation of High-Frequency Gravitational Waves (HFGW) by Means of an Array of Micro- and Nano-devices," *Gravitational-Wave Conference*, edited by P. Murad and R. Baker, The MITRE Corporation, Mclean, Virginia, May 6-9, 2003, Paper HFGW-03-117.

- Baker, R. M. L., Jr., "Precursor Experiments Regarding the Generation of High-Frequency Gravitational Waves (HFGW) by Means of Using an Array of Micro- and Nano-Devices," *Space Technology and Applications International Forum (STAIF-2004)*, edited by M. S. El-Genk, American Institute of Physics, Melville, New York, February 8-12, 2004, Paper F02-2-179.
- Chapline, G. F., Nuckolls, J., and Woods, L. L., "Gravitational-Radiation Production Using Nuclear Explosions," *Physical Review D.*, **10**, Number 4, August, 1974, pp. 1064-1065.
- Chiao, R. Y., "Superconductors as Transducers and Antennas for Gravitational and Electromagnetic Radiation," *arXiv:gr-qc/0204012 v2*, April 11, 2002.
- Chincarini A. and Gemme, G., "Micro-wave Based High-Frequency Gravitational Wave Detector," *Gravitational-Wave Conference*, edited by P. Murad and R. Baker, The MITRE Corporation, Mclean, Virginia, May 6-9, 2003, Paper HFGW-03-103.
- Cruise, A. M. (2000), "An electromagnetic detector for very-high-frequency gravitational waves," *Class. Quantum Gravity*, **17**, 2000, pp. 2525-2530.
- Dehnen, H. and Romero-Borja, F., "Generation of GHz – THz High-Frequency Gravitational Waves in the Laboratory," *Gravitational-Wave Conference*, edited by P. Murad and R. Baker, The MITRE Corporation, Mclean, Virginia, May 6-9, 2003, Paper HFGW-03-102.
- Fontana, G., "A possibility of Emission of High Frequency Gravitational Radiation from Junctions between d-wave and s-wave Superconductors," *Preprint, Faculty of Science, University of Trento*, 38050 Povo (TN), Italy, 1998, pp. 1-8 and <http://xxx.lanl.gov/html/cond-mat/9812070>.
- Fontana, G. and Baker, R. M. L., Jr., "The High-Temperature Superconductor (HTSC) Gravitational Laser (GASER)," *Gravitational-Wave Conference*, edited by P. Murad and R. Baker, The MITRE Corporation, Mclean, Virginia, May 6-9, 2003, Paper HFGW-03-107.
- Fontana, G., "Design of a Quantum Source of High-Frequency Gravitational Waves (HFGW) and Test Methodology," *Space Technology and Applications International Forum (STAIF-2004)*, edited by M. S. El-Genk, American Institute of Physics, Melville, New York, February 8-12, 2004, Paper F02-1-143.
- Grishchuk, L. P., "Electromagnetic generators and detectors of gravitational waves," *Gravitational-Wave Conference*, edited by P. Murad and R. Baker, The MITRE Corporation, Mclean, Virginia, May 6-9, 2003, Paper HFGW-03-119.
- Halpren, L. and Jovet, B., "On Stimulated Photon-Graviton Conversion by an Electromagnetic Field," *Annale H. Poincaré*, **VII**, NA1, pp. 25ff. (1968).
- Li, Ning , "Measurability of AC gravity fields," *Gravitational-Wave Conference*, edited by P. Murad and R. Baker, The MITRE Corporation, Mclean, Virginia, May 6-9, 2003, Paper HFGW-03-106.
- Li, Fang-Yu, Tang, Meng-Xi and Shi, Dong-Ping , "Electromagnetic response for High-Frequency Gravitational Waves in the GHz to THz band," *Gravitational-Wave Conference*, edited by P. Murad and R. Baker, The MITRE Corporation, Mclean, Virginia, May 6-9, 2003, Paper HFGW-03-108.
- Navarro, E., Portilla, M., and Valdes, Jose Luis, "Test of the Generation of High-Frequency Gravitational Waves by Irradiating a Multidielectric Film," *Space Technology and Applications International Forum (STAIF-2004)*, edited by M. S. El-Genk, American Institute of Physics, Melville, New York, February 8-12, 2004, Paper F02-3-141.
- Portilla, M. and Lapedra, R., "Generation of High Frequency Gravitational Waves," *Physical Review D* **63**, pp. 044014-1 to 044014-7 (2001).
- Portilla, M., "Generation of HFGW by Irradiating a Multidielectric Film," *Gravitational-Wave Conference*, edited by P. Murad and R. Baker, The MITRE Corporation, Mclean, Virginia, May 6-9, 2003, Paper HFGW-03-112.
- Rudenko, V. N., "Optimization of Parameters of a Coupled Generator-Receiver for a Gravitational Hertz Experiment," *Gravitational-Wave Conference*, edited by P. Murad and R. Baker, The MITRE Corporation, Mclean, Virginia, May 6-9, 2003, Paper HFGW-03-113.
- Stephenson, G. V., "The Application of High-Frequency Gravitational Waves (HFGW) to Communications," *Gravitational-Wave Conference*, edited by P. Murad and R. Baker, The MITRE Corporation, Mclean, Virginia, May 6-9, 2003, Paper HFGW-03-104.
- Weber, J., "Detection and Generation of Gravitational Waves," *Physics Review*, **117**, Number 1, pp.306-313, (1960).