Develop Solid State Laser Sources
for High Resolution Video Projection Systems

Federal Manufacturing & Technologies

B. K. Brickeen

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Final Report/Project Accomplishments Summary

CRADA Number 98KCP1057

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Date: 9/22/2000

Revision: 0

A. Parties

The project is a relationship between

Honeywell Federal Manufacturing & Technologies (FM&T)

2000 E 95th Street

PO Box 419159

Kansas City, MO 64141-6159

and

Magic Lantern (formerly ArcLaser)

9875 Widmer

Lenexa, KS 66215

B. Background

Magic Lantern, established in 1995 as ArcLaser Technologies L.L.C., researches and develops key component manufacturing of laser imaging systems. The company, which has strategic alliances with similar businesses, pursued this CRADA with Honeywell FM&T to help with the feasibility assessment and technical development of lower-cost, visible light solid-state laser sources to use in their laser projector products.

Specifically, Magic Lantern hoped to create a new family of video displays that use lasers as light sources. The displays would project electronic images up to 15 meters across and provide better resolution and clarity than movie film, up to five times the resolution of the best available computer monitors, up to 20 times the resolution of television, and up to six times the resolution of HDTV displays.

Honeywell FM&T's Laser and Electro-Optics Group develops and manufactures rugged, compact laser and electro-optics systems for weapons systems. The group also provides custom laser and electro-optics systems to the national laboratories and other federal agencies for many applications. The organization has produced high quality and high reliability products for many years, drawing on broad-based facilities and capabilities to design, fabricate, and test state-of-the-art systems. An experienced technical staff ensures reliable current photonic technologies and innovations to push the technical envelope into the future.

C. Description

Magic Lantern and Honeywell FM&T worked together to develop lower-cost, visible light solid-state laser sources to use in laser projector products. Work included a new family of video displays that use lasers as light sources. The displays would project electronic images up to 15 meters across and provide better resolution and clarity than movie film, up to five times the resolution of the best available computer monitors, up to 20 times the resolution of television, and up to six times the resolution of HDTV displays.

D. Expected Economic Impact

The products that could be developed as a result of this CRADA could benefit the economy in many ways, such as:

1. Direct economic impact in the local manufacture and marketing of the units.
2. Direct economic impact in exports and foreign distribution.
3. Influencing the development of other elements of display technology that take advantage of the signals that these elements allow.
4. Increased productivity for engineers, FAA controllers, medical practitioners, and military operatives.

Magic Lantern believes, based on internal and external market surveys, that movie theater operators will install digital laser movie projectors if the price is approximately \$60,000. Replacing half of the 22,000 screens in the U.S. over four years represents gross sales of \$660 million dollars. The added benefits of faster, less-expensive movie editing and distribution are difficult to assess, but should be comparable, as

are the service and distribution base.

Increased productivity in engineering and medical activities, predicated on the ability of practitioners to view more dynamic data at one time, is difficult to quantify. Given the perception of this increase, along with video signals they require, we can quantify somewhat the market for extremely high-resolution workstations at 1,000 units per year, \$20,000 each, for \$20 million dollars, which totals \$80 million over product life.

E. Benefits to DOE

The Direct Optical Initiation (DOI) program uses a solid-state laser pulse to initiate a detonation sequence in a weapon system. Traditionally, this program used a flashlamp-pumped, Cr:Nd:GSGG laser to provide the required optical pulse. Flashlamp pumping has been recognized for years as an inexpensive method to produce large energy outputs from laser systems, and Cr:Nd:GSGG is a laser gain material with broad absorption bands that match well with the spectral outputs of the flashlamps. Additionally, the output from Cr:Nd:GSGG lasers has been demonstrated to be degraded very little by irradiation. This 'rad-hardness' property makes Cr:Nd:GSGG a desirable material to use in weapons components. Prototypes based on this technology have been developed with proven overall electrical to optical efficiencies approaching 5%. FM&T designs using Cr:Nd:GSGG for DOI fireset prototypes have overall electrical to optical efficiency approaching 2%. The FM&T design utilizes an 80 μ s (full width @ third peak) pump pulse from the flashlamp, which has been experimentally determined to produce the most efficient energy output from the laser. The Q-switch is triggered near the end of this pumping time to extract the maximum energy per pulse from the laser rod.

Some weapon systems, however, require rapid firing of the laser in a time to fire that is much shorter than the FM&T 80 μ s standard. In this instance, a predetermined timing signal is not present to start the laser pumping. Rather, a trigger signal arrives in a random time with respect to a known reference signal. The laser is therefore required to provide an output at a random time within an acceptable operating window.

Employing traditional laser methodology, where the laser is pumped after receiving the trigger signal, requires a very intense burst of pump light in the random firing scenario. To deliver the required optical energy in such a short timeframe pushes the flashlamp state-of-the-art, perhaps beyond the bounds of what is achievable with flashlamp technology. Other methods of delivering the optical energy to the laser gain medium are feasible, such as chemical pumping, but these methods also have negative aspects. Even if sufficient pump energy can be delivered within the required time interval, using Cr:Nd:GSGG is still problematic. The broadband light from these pump sources excites the Cr ions, which deliver the energy via non-radiative transfer to the Nd ions with about 90% efficiency. The time for this Cr to Nd transfer process has been measured to be 10 – 17 μ s, which is pushing the acceptable function time for laser initiation.

Furthermore, flashlamp pumping requires high voltage within the fireset of several kilovolts. It is desirable to begin developing expertise with laser diode pumping of the DOI prototypes in anticipation of transitioning to designs that eliminate high voltage. Laser diodes could be used with Cr:Nd:GSGG, or even Nd:GSGG, to directly pump the Nd ions and bypass the lag time for energy transfer between the Cr and Nd dopants. However, pumping the required energy in the shorter timeframes requires a large quantity of diodes operating at high operating currents. Facet damage is a concern, as the peak powers required from each diode emitting region would necessarily approach the damage threshold for the devices.

One approach for delivering an optical pulse within the rapid time-to-fire (RTTF) requirements is to maintain an optical inversion within the laser rod throughout the defined operating window. In this case, once the trigger is received, the time to output is simply the pulse buildup time within the laser resonator. The pulse buildup time for an EO Q-switched solid-state laser is typically a few hundred nanoseconds or less, which easily meets the function time specification. This is doable by using diode lasers to pump the solid-state laser in a CW mode throughout a defined window to maintain the necessary optical inversion.

The technologies necessary to produce the visible light lasers required by Magic Lantern are in many ways similar to those required by the proposed RTTF laser. And, a specific mechanism for producing blue laser light requires a three-level laser transition within the Nd ion energy levels. Increased expertise with three-level laser transitions is also useful in the RTTF laser, as certain three-level laser materials have the potential for up to a four-fold increase in laser output energy under the same pumping conditions. This CRADA has provided the funding whereby the proof-of-concept experiments and other technical research have been accomplished.

F. Industry Area

The first application will be to create a digital movie theatre projection system, where movies that are brighter and crisper than film are projected digitally and distributed via satellite, video disk, or fiber optics. These projectors will also allow live images to be shown at the theater, such as sporting events, concert remotes, and breaking news. Also, large surrounding images, such as Imax- and Omnimax-type displays, will be available, pre-produced and live. Movie production, now done digitally, would not have to proceed through the slow, expensive, and image-degrading process of outputting the movies to film.

Also, the new technology permits the development of very high resolution monitors, with up to 10 times the data content of current monitors, which creates faster, more accurate medical image interpretation for radiologists and other physicians. It also provides concurrent display of engineering data, to give engineers more data at once to aid creativity, manipulation of digital photographic images for the advertising industry, and faster interpretation of intelligence imagery from satellites and remotely-piloted vehicles, keeping the U.S. ahead in military technology.

To achieve this goal, the company development plan is to proceed as follows:

1. A new approach to controlling lasers to produce imagery will be developed, where the switching of the light is done inside the laser, instead of modulating the light after it emits from the laser. While internal laser physics is well understood and switches are available to switch the light in a discrete (on-off) manner, no one has fabricated a switch controlled by a video signal. This technique could dramatically increase the brightness of a particular laser, thus reducing the size and power of the laser, and the cost for a particular installation.
2. New solid state laser materials have been developed recently for high-energy research, although they have yet to be introduced to the marketplace, mostly due to the lack of perceived applications. FM&T will test samples of these materials to learn how they might enhance our objectives when compared with available commercial materials.
3. A new multi-line laser scanning optical technique will be developed that allows for the concurrent display of four to eight times current levels of data in a single moving display image. FM&T's challenge is to fabricate and control light through optical fibers many times smaller than a human hair, so that many different pieces of video information are displayed concurrently.

Magic Lantern intends to produce a proof-of-concept demonstration of the technology required for such a product. Once the proof-of-concept is complete, all three improvements will be integrated into

prototypes that are sized for varying markets, such as:

1. A theater movie projector that uses the new Grand Alliance HDTV video signal as a source. This image source is emerging as a national standard and, with an adequate projector, gives nearly twice the resolution of a film movie projector.
2. A 1-to-3 meter monitor with resolution equivalent to a large professionally prepared photograph.
3. A motion picture projector with a display at 12 times movie resolution, to be viewed in venues similar to Imax and Omnimax. Such displays would also serve remote sporting and concert audiences, product announcements, and other advertising shows.

By far, the movie projector is the product Magic Lantern is focusing its development efforts on. This product can make an impact on the movie industry in that the distribution of new movies will be drastically altered, creating new programs to show to new and existing customers.

1. Each showing can be from a satellite feed, fiber optic transmission, or video disk, rather than a film print, whose cost ranges from \$900 to \$2,000 each for 35 mm (with between 600 and 1600 copies per movie) totaling up to \$3.2 million. The figures are even higher for 70 mm.
2. Distribution can occur when production is complete, rather than after creation of hundreds of copies, saving several months interest on production costs.
3. Digitally created and/or edited movies can be distributed directly, rather than after the 8-minutes-per-frame process of transferring the digital information to movie film, a release-date delay of up to eight months.
4. Theaters can be revitalized with real-time movie quality events, concerts, sporting events, and breaking news, thereby increasing profits considerably for cinema owners.
5. Interactivity, while not yet successful due to underdeveloped program material and techniques, will be more attractive, and further specific to theaters, drawing more customers and increasing concessions, which typically represent 48% of new profit.
6. While not a direct movie application, the same projector could be distributed for interactive teaching methods with universities linked via the large screen, with courses offered by the best U.S. instructors.

Current monitor standards of 1280 x 1024 pixels provide nearly all the resolution needed for word processing and spread sheets. However, increased resolution has a market for special uses, such as:

1. FAA air traffic control workstation (requires 2000 x 2000 pixels).
2. Engineering workstations, where detail discernment and simultaneous presentation of many documents are important.
3. Photographic workstations, since none today can simultaneously display all the information contained in a desktop-sized photograph.
4. Medical imagery, where resolution is vital, but also critical is the accurate representation of image intensity levels over a wide dynamic range.
5. Intelligence operations, where massive amounts of imagery must be evaluated quickly and accurately, now that unmanned reconnaissance vehicles are emerging.

The Magic Lantern product is also environmentally friendly. Today, the movie industry uses large quantities of silver halide-based film. The film and the chemicals used to process the film are environmental hazards. Soluble salts of silver, as occurring in the bleach and fix process of development, are cumulatively heavy metal poisons, toxic in the milligram range. A significant portion of the total

output of silver mining and its attendant environmental and health hazards are used specifically in the production of movie-based film silver. Magic Lantern believes that replacing film projectors with digital projectors will favorably impact the environment.

To produce the proposed projector requires a visible light laser in three colors, red, green, and blue. The laser sources account for most of the cost of the projector. The goal is to acquire or produce the visible light at a cost of \$20,000 per color or less.

G. Project Status

All milestones were completed as scheduled with the exception of milestone 7, *Package Design*. Budget cuts forced this milestone to be eliminated.

H. Point of Contact for Project Information

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I. Company Size and Point of Contact

Magic Lantern employs three full-time employees and several part-time staff, with contractors hired as needed. Its annual sales information is considered proprietary. The person responsible for the project, who is also the contact for this CRADA, is:

Jeff Pease

(913) 307-9777

(816) 468-8358 fax

J. Project Examples

See photographs of the three visible light lasers running simultaneously.

K. Technology Commercialization

Magic Lantern intends to commercialize this technology into a digital movie projector and potentially other display and/or printing products. They're regarding their marketing plans as proprietary.