Application of High Powered Lasers to Drilling and Completing Deep Wells

FWP-49066

Goal:
The goal is to develop new, more efficient, cleaner ways to drill and perforate wells through hard rock formations encountered at greater depths. The objective is to extend previous studies of laser drilling, determining: if large holes can be created by lasing small holes adjacent to each other; if lasers can cut rock when submerged in water; how a laser might be employed for perforating; and the effects of wavelength on rock removal.

Laser perforating reservoir rock

Background:
This project is a continuation of two previous studies. The first, funded by Gas Technology Institute (GTI), used high-powered military lasers to show that lasers could cut all rock types and that super-high power is not needed to spall, melt, and vaporize rock. The second study, funded by NETL, used two lasers at Argonne National Lab to quantify the minimum amount of energy required to cut and melt rock, and to define the laser parameters for efficient cutting of various rock types.

Laser technology applied to drilling and completion operations is attractive primarily because of its potential to reduce drilling time. Lasers cut drilling time by not contacting the rock, eliminating the need to stop and replace a mechanical bit. When using laser technology for perforation, the rock is left cleaner, and fluid flow paths for oil and gas production are damaged less. Researchers believe that state-of-the-art lasers have the potential to penetrate rock 10 to 100 times faster than conventional boring technologies – a huge benefit in reducing the high costs of operating a drill rig. Other potential benefits of using a laser include the creation of a melted rock wellbore lining. This can eliminate the need for steel casing, and improve flow performance, if used as a perforator.

The lasers used in this project included a 6 kw carbon dioxide laser capable of continuous wave, electric-chopped pulsed and super-pulsed beams, and a 1.6 kw neodymium yttrium aluminum garnet (Nd:YAG). It is also capable of a wide range of pulse widths and repetition rates. The Nd:YAG laser was recommended for future tests due to its optical fiber delivering capacity and smaller energy loss in water. Disk samples, three inches in diameter, varying from 0.5 to 2.5 inches were employed for laser testing. Berea sandstone, limestone, and shale rock samples were used.

Performers:
Argonne National Laboratory (ANL) – Project management and all research products, Time on laser equipment & expertise, Laser physics expertise, Diagnostic instrumentation & expertise, Modeling of laser/rock interaction

Parker Geoscience Consulting, LLC – Test plans, Data analysis, Industry contacts

Colorado School of Mines – Acquire and prepare rock samples, Analyze before and after laser exposure, Contribute acquired laser/rock expertise, Industry contacts

Location:
Argonne, IL 60439
Golden, CO 80403
Golden, CO 80401

Potential Impact:
Currently the Oil and Gas Industry spends hundreds of millions of dollars a year to clean up perforation damage in order to optimize well production. Even with this effort, production optimization is sometimes lacking due to the inability to remove all damage caused by perforating. When this occurs some of the oil and gas is often left in the ground.

Results:

- Identified laser–rock interaction mechanisms;
- Recognized laser spallation being the most energy efficient mechanism;
- Obtained true laser specific energy for drilling or perforting of different rocks;
- Developed rotary laser rock drilling technique;
- Performed multi-overlapping spot tests to show that large diameter holes can be created efficiently by using a pattern of overlapped small laser spots;
- Proved that laser power levels needed to drill rock efficiently in this mode are in the range that optical fiber cables are capable of delivering;
- Demonstrated that both Nd:YAG and CO2 laser beams can penetrate water of certain depths above rock and cause rock destruction, although the degree of destruction is significantly reduced compared to dry sample data;
- Demonstrated that high power lasers have the ability to drill clean holes to a certain depth before melting occurs, and that the introduction of a gas purge system benefits laser perforation;
- Demonstrated that there is not a great difference in rock volume removed per total energy density between lasers of different wavelengths suggesting that lower powered lasers could perforate and drill in rock;
- Demonstrated that fairly hard rocks can be penetrated at reasonable rates,
- Began laser rock perforation;
- Initial tests of laser drilling of rocks through water;
- Sensor-embedded rock specimens;
- Compact laser drilling head;
- Dry-zone drilling nozzle;
- Data acquisition system;
- Perforated six-inch deep hole;
- High power laser beam switching tests; and
- Started Modeling of laser spallation of rocks.

Current Status and Remaining Tasks:
This project has been completed.

Project Start: May 1, 2002
Project End: April 30, 2005

DOE Contribution: $935,000
Performer Contribution: 0

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ANL – David K. Schmalzer (schmalzer@anl.gov or 630-252-7723)

Additional Information:
Annual Report [PDF-2086KB]
Laser Use for Well Drilling
Laser Rock Interaction [PDF]

Pertinent Publications:
Z. Xu, C. B. Reed, R.A. Parker, R. Graves, “Laser spallation of rocks for oil well drilling,” proceedings of 23rd International Congress on Applications of Laser & Electro-Optics, October 4-7, 2004, San Francisco, California.

Z. Xu, C. B. Reed, R. graves and R. A. Parker, “Rock perforation by pulsed YAG laser,” proceedings of 23rd International Congress on Applications of Laser & Electro-Optics, October 4-7, 2004, San Francisco, California.

Z Xu, SPE, Y. Yamashita*, C. B. Reed, “Modeling of Laser Spallation Drilling of Rocks for Oil Well Drilling” Submitted to 2005 Society of Petroleum Engineers (SPE) Annual Technical Conference and Exhibition (ATCE), 9-12 October, Dallas, Texas, USA

Bailo, E.T.and Graves, R.M.: “Analytical Techniques for Evaluating and Modeling the Alterations of Reservoir Rocks due to High-Power Lasing,” paper presented at the 2004 Rocky Mountain Section AAPG Meeting, Denver, CO USA, August 9-11, 2004.

Bailo, E.T. and Graves, R.M.: “Spectral signatures and optic coefficients of surface and reservoir shales and limestones at COIL, CO2 and Nd: YAG laser wavelengths,” presented at the International Symposium on Optical Science and Technology (the SPIE 49th Annual Meeting) held 2-6 August 2004 at the Colorado Convention Center in Denver, Colorado USA. SPIE Code Number: 5538-19.

Graves, R.M. and Bailo, El Tahir.: "Porosity and Permeability Changes in Lased Rocks Calculated Using Fractal Fragmentation Theory." paper is presented at the Petroleum Society’s 5th Canadian International Petroleum Conference (55th Annual Technical Meeting), Calgary, Alberta, Canada, June 8 – 10, 2004.