AAPG Search and Discovery Article #90023©2002 AAPG Southwest Section Meeting, Ruidoso, New Mexico, June 6-8, 2002 (2003)

Ramona M. Graves, Colorado School of Mines
Samih Batarseh, Gas Technology Institute

Application of High Power Laser Technology to Laser/Rock Destruction: Where Have We Been? Where Are We Now?

ABSTRACT

In 1997, a research project funded by the Gas Research Institute (now Gas Technology Institute) titled "Determining the Benefits of Star Wars Laser Technology for Drilling and Completing Oil and Gas Wells" was begun in the Petroleum Engineering Department at the Colorado School of Mines. The goal of this two-year project was to examine the feasibility, costs, benefits and environmental impact of applying laser technologies to drill and complete oil and gas wells. The project used the Mid-Infrared Advanced Chemical Laser (MIRCAL) at the U.S. Army's HELSTF facility in White Sand, NM, the Chemical Oxygen-Iodine Laser (COIL) at U.S. Air Force's Directed Energy Research facility in Albuquerque, NM, and a CO_2 and CO laser at the P.N. Lebedev Institute in Moscow, Russia.

The second phase of this research, funded by the US Department of Energy, the Gas Technology Institute, PDVSA, and Halliburton, continued the process of determining critical laser parameters and rock properties needed to adapt available high power lasers to oil and gas operations. Laser-rock testing conducted at Argonne National Laboratory (ANL) using the Nd:YAG laser focused on quantifying specific energy so comparisons could be made with traditional rotary drilling techniques. The laser beam generated by the Nd:YAG is delivered using fiber optics. Research continues at ANL using both an Nd:YAG and a CO_2 laser. Plans to lase rocks under stimulated reservoir conditions of saturation and pressure are currently being prepared. The free electron laser and the diode laser are also being used for comparison.

The research showed the potential value of the laser drilling research, including:

- Proving a laser's ability to cut through rock more quickly than conventional and other non-conventional methods.
- Determined the power required to chip, melt, or vaporize many rock types including sandstones, limestones, shales, granite and salt.
- Showed that lasers can destroy rock without damaging formation permeability and, depending on laser and rock parameters can even enhance permeability. When desired a laser can also be used to melt rock, forming a natural casing.
- Effects of lasers on other rock properties, such as porosity, mechanical strength, phase change, have be quantified.
- Lasers destroy rock at using less specific energy than previously reported in the literature.

Over 300 hundred rock samples; sandstone, limestone, shales, granite, concrete, and salt, under varying test conditions; unsaturated, saturated, stressed, lasing through mud and water have been examined. The prospective benefits of laser/rock destruction are many.

Application of High Power Laser Technology to Laser/Rock Destruction: Where Have We Been? Where Are We Now?

Ramona M. Graves, Colorado School of Mines
Samih Batarseh, Gas Technology Institute

June 8, 2002

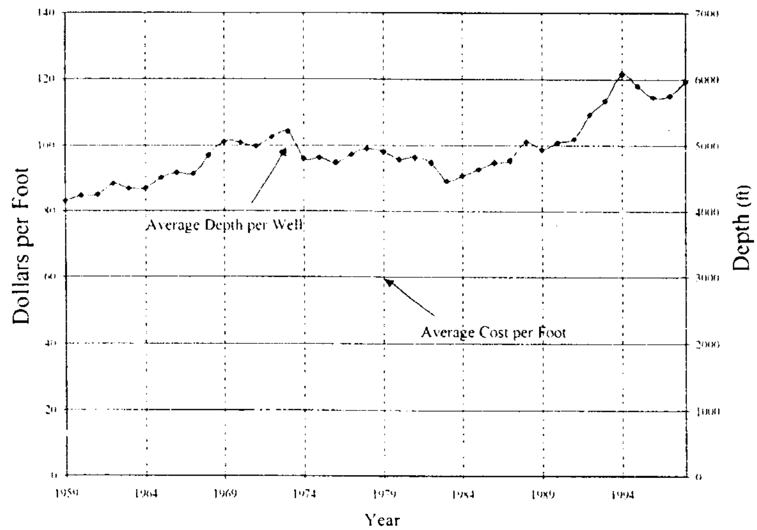
Presented at
SW AAPG Convention
Ruidoso, New Mexico

CSM

HOW IT GOT STARTED

- 1994 Congress mandated that cold war military defense technology be transferred to American industry.
- 1997 Gas Research Institute (now Gas Technology Institute) put forth an RFP to REVOLUTIONIZE DRILLING.
  - Cable Tool Drilling - impact action of bit. Developed in China 1300 A.D. First used to drill in U.S. for oil in 1859.
  - Rotary Drilling – turn to the right. Developed in France in 1860s. First used to drill in U.S. for oil in 1901.1997
- 1997 Petroleum Engineering Department at the Colorado School of Mines brought the research idea to GRI to combine the two.

CSM



Estimated Cost Per Foot and Average Depth Per Well of All Wells (Oil, Gas and Dry) Drilled Onshore in the U.S. from 1959 - 1999 (DeGolyer and MacNaughton, 2000)

CSM

RESEARCH CONDUCTED IN PHASE ONE

1997-2000 Funded by the Gas Research Institute (now Gas Technology Institute)

Objective: Determine the feasibility of applying high power lasers to drill and complete oil and natural gas wells

Methodology: Used four lasers with different power and wave length and eleven "rock types" with different porosity, permeability, and mineralogy

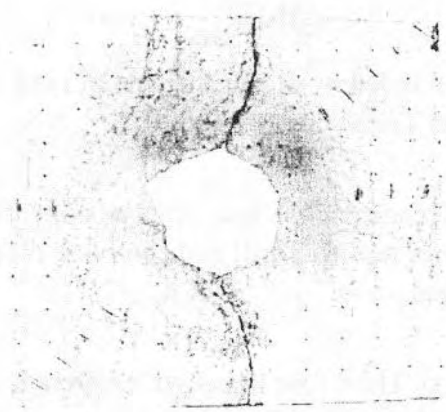
CSM

LASERS

- Mid-Infrared Advanced Chemical Laser (MIRACL)
  - US Army in White Sands, NM
  - Wavelength 2.6 to 4.2 μm, Power 1200 kW
- Chemical Oxygen Iodine Laser (COIL)
  - US Air Force in Albuquerque, NM
  - Wavelength 1.315 μm, Power 100 kW
- Pulsed CO Laser
  - Lebedev Institute, Moscow, Russia
  - Wavelength 5 to 6 μm, Power 200 kW
- Pulsed CO_2 Laser
  - Lebedev Institute, Moscow, Russia
  - Wavelength 10.6 μm, Power 1000 kW

CSM

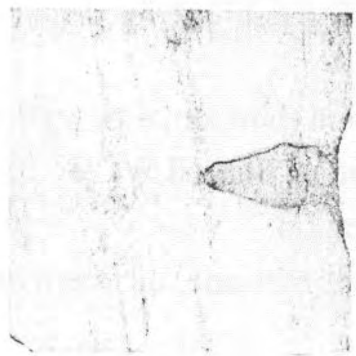
MIRACL



Berea Yellow Sandstone Lased to Simulate Drilling. Block Dimensions 12 x 12 x 3 inches, Hole Diameter 6 inches, ROP = 170 ft/hr.

CSM

MIRACL



Berea Yellow Sandstone Lased to Simulate a Perforation. Block Dimensions 12 x 12 x 3 inches, Hole Diameter 2 inches, ROP > 450 ft/hr.

CSM

CHEMICAL OXYGEN IODINE LASER (COIL)

- Laser physical size (footprint) optimized as part of the Airborne Laser (ABL) Research Project
- Available at Kirtland Air Force Base, Albuquerque, NM
- Fiber Optic Deliverable

CSM

CONDITIONS VARIED

- Rock Type
- Laser Power
- Beam Direction (horizontal or vertical)
- Continuous and Chopped Wave
- Stress Orientation
- Saturation (air, methane, oil, fresh and salt water)
- Lased Through Drilling Mud
- Sample Shape
- Purge Gas

CSM

ROCKS

	Porosity (%)	Permeability (md)
Sandstone		
Berea Yellow (BY)	23	6000
Berea Gray (BG)	21	500
Mesaverde Reservoir (Sst)	18	10 to 200
Limestone		
Reservoir 1 (Ls1)	6	0.02
Reservoir 2 (Ls2)	6	0.03
Shale		
Reservoir 1 (Sh1)	2	0.31
Reservoir 2 (Sh2)	3	0.20
Granite (GW and GF)		
Concrete and Salt		

CSM

LASED BEREA (BY) - COIL

CSM

RESEARCH CONDUCTED IN PHASE TWO

2000-2001 Funded by the US Department of Energy (DOE) and Gas Technology Institute (GTI)

Partners: Colorado School of Mines, Argonne National Labs, Halliburton, PDVSA

Objective: Build on results from Phase One. Determine absolute specific energy, optimum beam type and study physics of laser-rock interaction

Methodology: Use two lasers with different power and wavelength and three rock types

CSM

EXPERIMENTAL METHOD

Compare: "Efficiencies" (specific energy) between various drilling methods.

Lasers: CO_2 and Nd: Yag

Rocks: Sandstone, Limestone, Shale

Result: Specific energy required for rock removal with lasers is comparable to rotary drilling.

$$SE = \frac{\text{Energy Input}}{\text{Volume Removed}} = \frac{kJ}{cm^3}$$

CSM

CONCLUSIONS

- Existing lasers have enough power to penetrate all rock types.
- Laser/rock interaction is a function of both the rock and laser type.
- More scientific study should be done to determine the controlling parameters.
- Laser candidates identified:
  - MIRACL - HF(DF) hydrogen fluoride, deuterium fluoride
  - COIL - Chemical Oxygen Iodine Laser
  - CO_2
  - CO
  - Nd:YAG - Neodymium: yttrium aluminum garnet
  - Diode - Solid State

CSM

OTHER APPLICATIONS

- Perforating
- Casing while drilling
- Determine mineralogy while drilling
- Cutting windows in cased holes
- Multi-lateral completions
- Seismic shot holes
- Stuck pipe
- Water shut-off
- Delineating reservoirs and ore deposits
- Etc,etc,etc ....

CSM

STILL TO CONSIDER

- Laser beam delivery
- Portability
- Environmental issues
- Economics considerations
- Pressure control
- In-situ conditions
- System design
- WHAT CONTROLS SPALLING, MELTING AND VAPORIZATION!

CSM

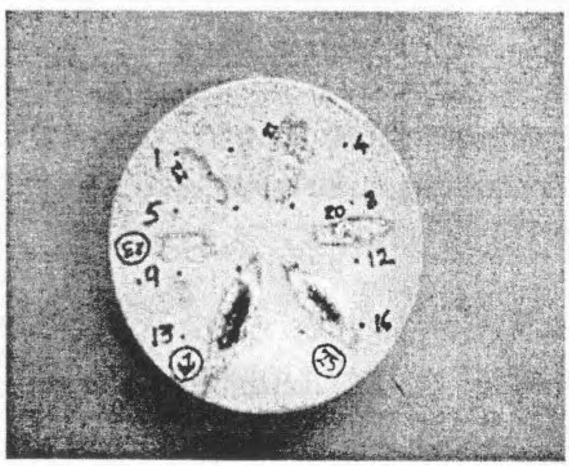
Typical Operating and Performance Data on Four Principal Laser Types

	Direct Diode ISL	CO2 Flowing	Nd:Yag Flash Pumped	Nd:Yag Diode Pumped
Net System Efficiency, % continuos operation at 100% Power including chiller	30%	6%	1%	6%
Hourly operating Cost $ at 100% Power	$1.50	$10.00	$30.00	$6.00
Wave Length micron	0.8	10.6	1.06	1.06
Absorption % - steel *	40%	12%	35%	35%
Absorption % - Aluminum *	13%	2%	7%	7%
Footprint for laser, power supply and Chiller, sq.ft	8 sq.ft	50 sq.ft	100 sq.ft	60 sq.ft
Replacement, Hours	Laser Arrays 10000 hours	Optics – 2000 hrs, Blower/Turbine 20-30000 hrs	Lamps – 1000 hrs	Pumping Arrays 10000 hrs
Laser/Beam Mobility	High/High	Low/Medium	Low/High	Low/High

* Higher percentage absorption means less reflected energy, and more efficient use of the laser beam

CSM

LASED BEREA (BG) - DIODE



CSM

Diode Laser Dimensions – Includes all auxiliary equipment except chiller

CSM

Details of GRI Study

- Graves, R.M. and Batarseh, S., 2001, "Determining the Benefits of Applying Star Wars Laser Technology for Drilling and Completing Oil and Gas Wells," Final Report to Gas Research Institute, Document No. GRI-01/0078.
- Graves, R.M. and Batarseh, S., 2001, "Laser Parameters that Effect Laser-Rock Interaction: Determining the Benefits of Applying Star Wars Laser Technology for Drilling and Completing Oil and Natural Gas Wells," Topical Report to Gas Research Institute, Document No. GRI-01/0079.
- Graves, R.M. and Batarseh, S., 2001, "Rock Parameters that Effect Laser-Rock Interaction: Determining the benefits of Applying Star Wars Laser Technology for Drilling and Completing Oil and Natural Gas Wells," Topical Report to Gas Research Institute, Document No. GRI-02/0080.
- Graves, R.M. and O'Brien, D.G., 1998, "Targeted Literature Review: Determining the Benefits of Star Wars Laser Technology for Drilling and Completing Natural Gas Wells," Topical Report to Gas Research Institute, Document No. GRI-98/0168.

CSM

Special Thanks for Technical Contributions

Richard Parker, Parker Geoscience Consulting
Brian Gahan, Gas Technology Institute
Claude Reed, Argonne National Laboratory
Zach Xu, Argonne National Laboratory
Jerry Jones, Native American Technology
Neal Skinner, Halliburton
Humberto Figueroa, PDVSA
Alejandro Lagreca, PDVSA
Jose Cantillo, Colorado School of Mines

CSM