Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

# Geothermal Well Completion Technology Using High Power Laser Device

Peter Bajcsi, Tamas Bozso, Robert Bozso, Imre Czinkota, Balazs Kovacs, Tivadar M. Toth, Felix Schubert, Janos Szanyi

Dept. of Mineralogy, Geochemistry and Petrology, University of Szeged, Egyetem u 2, Szeged, Hungary 6722

szanyi@iif.u-szeged.hu

**Keywords:** Laser drilling, lateral drilling.

**ABSTRACT**

The aim of our research team is to develop an economical and environmentally safe technology in subsurface laser drilling in Hungary.

To complement the known laser spallation drilling technology another conceptionally different laser drilling methodology is being developed, based on melting of the subsurface geological formations and the removal of debris. The technology may benefit both well completion and rework interventions in fluid mining, especially in geothermal energy and hydrocarbon production.

The drilling procedure is currently tested on different rock types in a high pressure chamber. The technology allows the operator to adjust the permeability of the borehole wall, keeping it closed or open for fluid communication at the operator's choice.

Laboratory measurements indicate that the technology will help save reservoir integrity and will increase drainage area resulting in low pressure gradient both production and injection wells.

## 1. INTRODUCTION

Thermal wells have been operated for over 140 years in Hungary. While there are more than 600 production wells operating on porous thermal aquifers, only a few injection wells have been drilled into sandstone as the direct use of thermal water without injection has been the standard procedure in Hungary. The technology aims to contribute to the methodology of a sustainable production and injection of fluids in geothermics, which is economical in the context of communal and agricultural heating operations and in addition to electricity production.

## 2. PRINCIPLES OF LASER DRILLING TECHNOLOGY

Recent developments in laser technology now enables us to use low energy loss high power laser devices (HPLD) even in large depths via the standard high carrying capacity optical fibers.

The HPLD will utilize cutting-edge, underbalance laser well completion and rework technology in fluid mining, including oil and gas as well as the geothermal industry. The tool is comprised of a surface located high power laser generator and a specially designed subsurface directional laser drilling head. The laser head is attached to a coiled tubing or an umbilical system.

The laser tool will superheat the subsurface formation, melt the target material and will remove the molten debris while the borehole is being drilled (Figure 1.). The technology allows the operator to adjust the permeability of the borehole wall. The result of this process is a highly permeable approx. 1-2 inch diameter lateral pointing into any desired direction (Figure 2.), with large active surface to increase either water production yields or to reduce the pressure gradient nearby the opened section of the well.

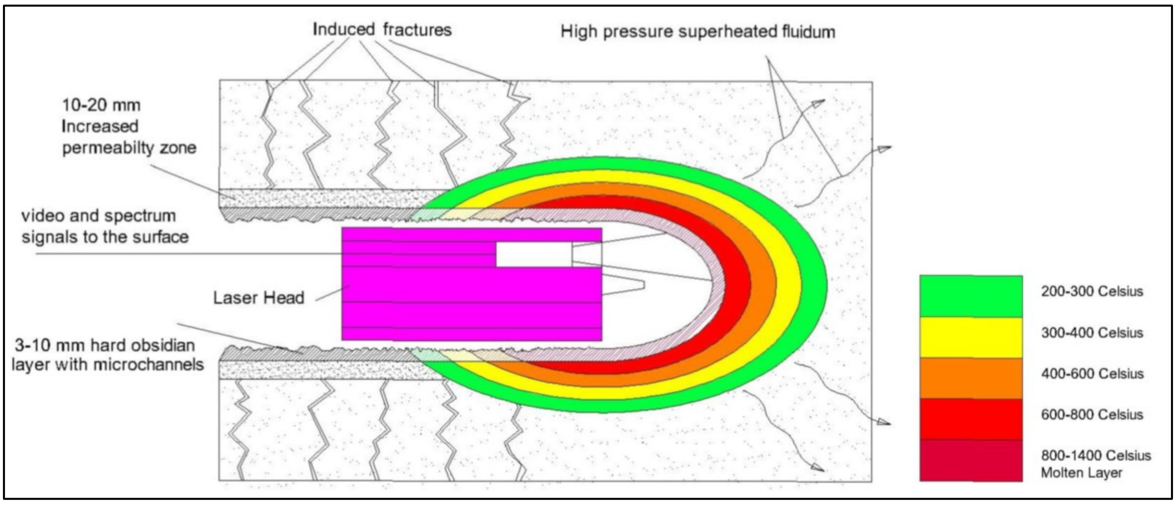


**Figure.1: Laser Drilling Process**

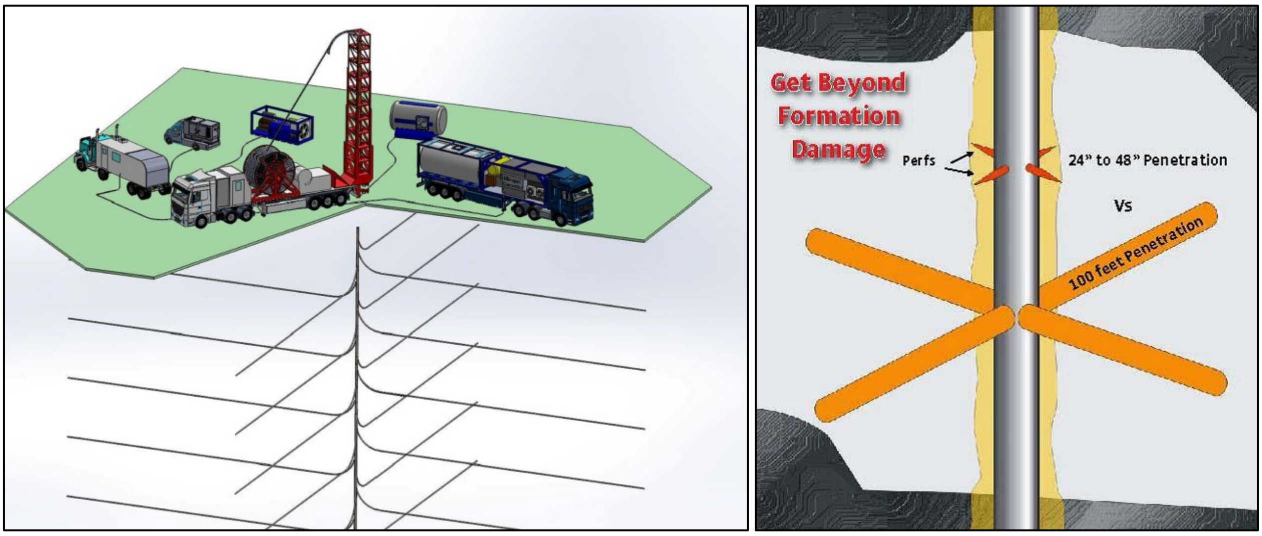


**Figure.2: Laterals drilled in Any Desired Direction**

Laser drilling complies with standard industry safety requirements and fits into existing drilling equipment to offer an in-situ, real-time fully controlled procedure with video and spectroscopy feedback to the operator, with no wearing parts, no chemicals and low maintenance while maintaining formation integrity and environmental safety.

The laser technology is especially well suited for economically drilling short laterals from existing wells in a single work phase, drilling through the casing, cement and the formation as well, with one tool in and out.

## 3. MATERIALS AND METHODS

To investigate the effects of HPLD on different rock types, a multitude of petrographical, non-destructive image analytical and hydraulic tests have been performed. To check the structure of the pattern formed at the walls of the laterals, petrographical thin sections were made and analyzed, meanwhile computer tomography and scanning electron microscope images were also taken and evaluated.

Dominantly sandstone core samples of large depths were tested due to their high importance for the Hungarian geothermal industry. The cylindrical samples were saturated with crude oil or brine depending on the test specification and a 30-60 sec. laser beam exposure of 3.2-8 kW power was applied using an inert gas (nitrogen) atmosphere. The laser tests were performed both on normal and high pressure in a 150-bar pressure chamber. The pre-saturated samples were shot in flooded conditions in the pressure chamber using different pressure gradients on the sample to simulate genuine field conditions.

On the plug samples helium porosity, nitrogen permeability, brine (5 g/l water solution of NaCl) porosity and brine permeability measurements were performed according to oil industry standards.

Both gas and water permeability were measured in vertical and horizontal directions using differently oriented plugs. Permeability measurements were made to compare the original state and post-laser treatment state of the top plane of the cylindrical (plug) samples. The methodology of API-RP 27 was applied for linear permeability measurements. At low permeability samples the pulse decay methodology was applied. The main objective of the measurement program was to observe permeability changes on the test samples as a result of laser treatment…


**Figure 3. Permeability Test Plug Samples Before and After Laser Treatment**

## 3. RESULTS

Different zones can be identified both on the petrographical thin section and the scanning electron-microscope and the CT images (Figure 4.). A melted zone is formed next to laser drilled borehole wall, consisting of numerous glass bubbles or a continuous glass mass. The thickness of the melted zone is up to 1.5-2.5 mm. Right below the molten material a synthered zone can be found where the heat shock was not enough to fully melt the rock but was strong enough to stick the grains together. Beyond the synthered layer the original rock matrix remained unaffected. The large heat shock caused several fissures of different apertures to emerge even at large pressure ranges (Figure 5.).

The thickness and the structure of the molten zone is highly dependent on the direction and the size of the pressure gradient as well as the laser power and the rock type. The continuous glass wall is highly impermeable, though the bubble structure may have almost the same or even a higher permeability than that of the original rock matrix (Figure 6.).

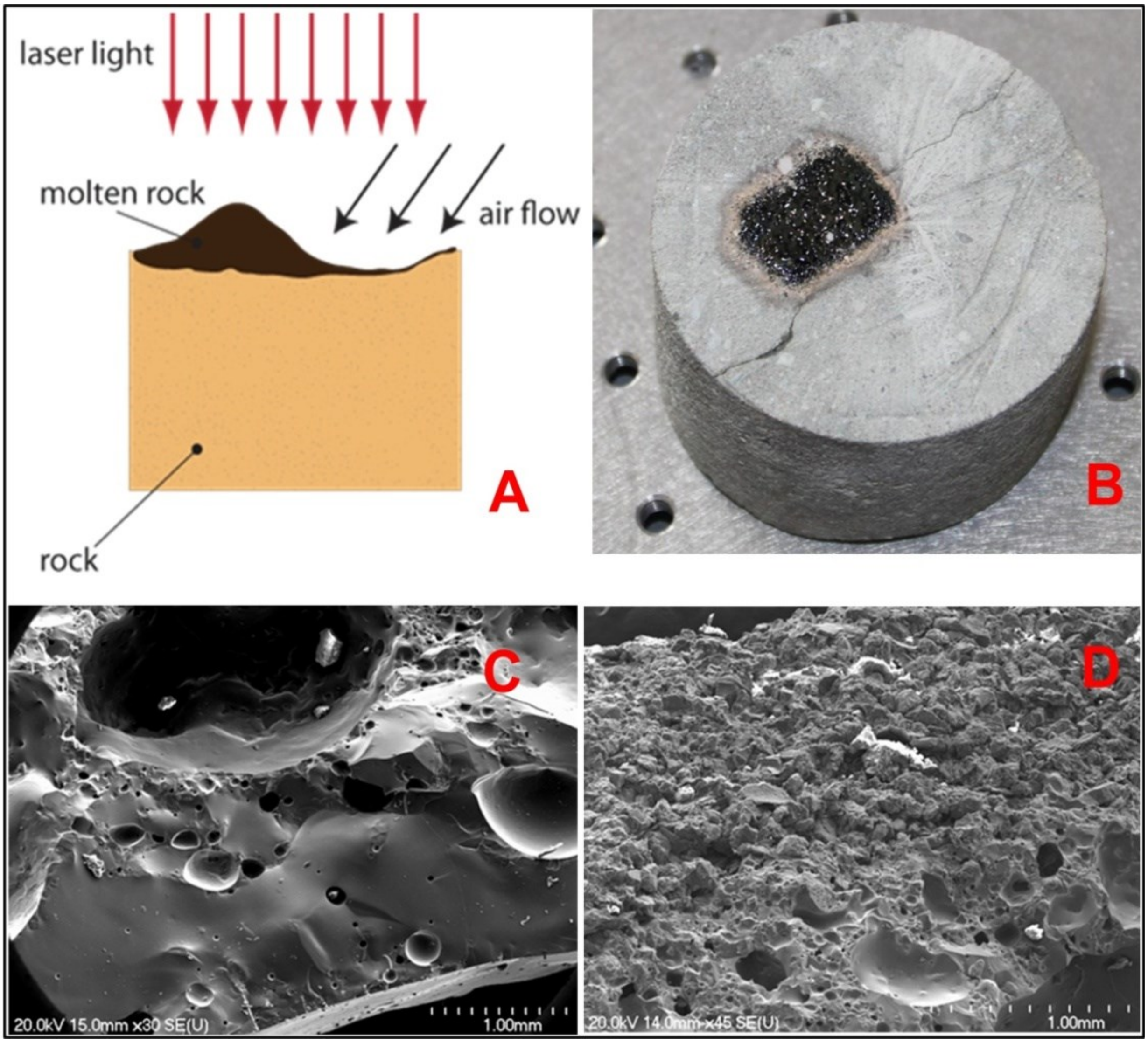


**Figure.4: A.) Rock melting and Removal by Laser, B.) Sandstone Sample with Molten Glass Layer, C.) Sealed Glass Layer (impermeable), D.) Open Glass Layer with Micro Channels (Permeable)**

Figure 7. presents the results of permeability measurements made by the Research Institute of Applied Earth Sciences Miskolc, Hungary (Bódi 2014). It can be seen that applying the bubble structured wall the permeability of the samples was not significantly changed though a permeability change of the rock samples occurs. The direction of the change could not be unambiguously stated. In some changes, the gas and/or liquid permeability of the sample increased. In some other cases decreased were measured. Nevertheless, it can be generally stated that the extent of the permeability change generally remains within 25 percent. This, unlike the effects of traditional jet perforation, will have no negative effect on hydraulic well performance (Bellarby 2009).

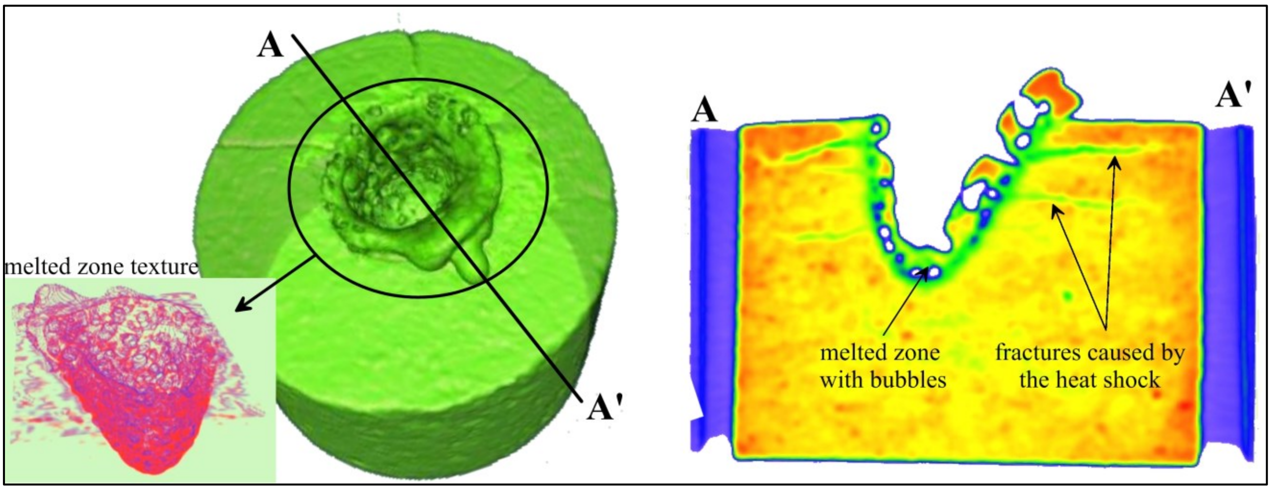


**Figure 5. 3D Structure and Cross Section of Laser Treated Sandstone Sample on Computer Tomography Images**

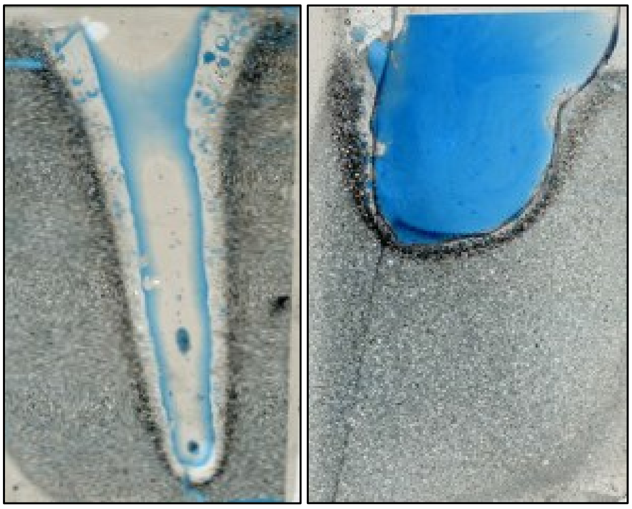

**Figure 6. Petrographical Thin Section of Laser Treated Samples High permeable thick bubble structure (left) and impermeable thin glass (right) at the wall of the laser drilled hole formed due to different pressure conditions. The voids (hole and bubbles) were filled by blue epoxy for technical reasons.**

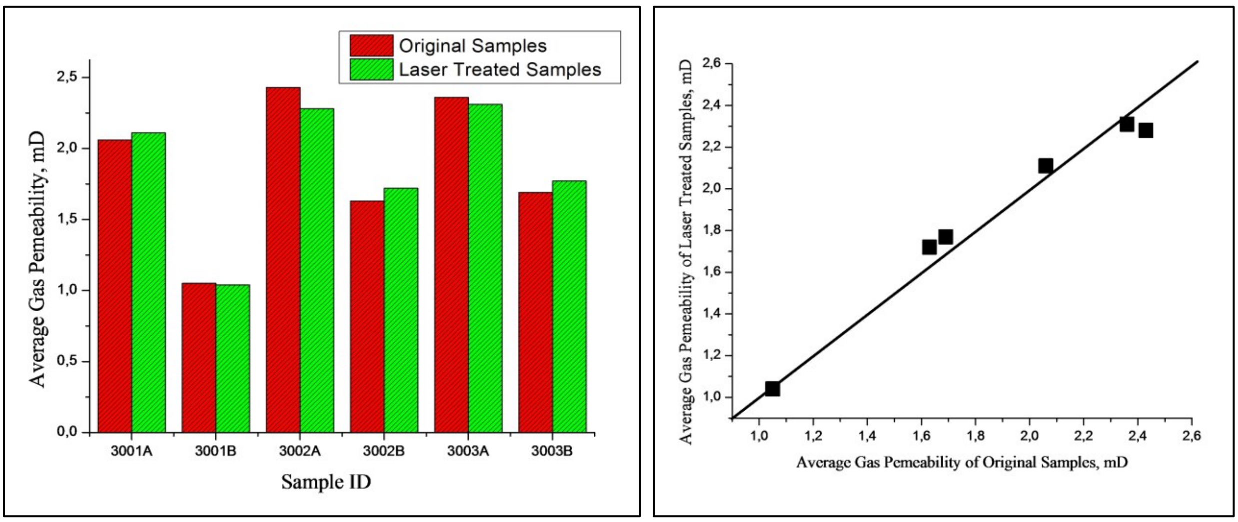


**Figure 7. Change of Gas Permeability Caused by Laser Treatment (left) and Cross Plot of Gas Permeability Results of Original and Laser Treated Samples**

Taking into account the permeability measurement results a hydraulic calculation was performed to determine the possible increase of production rate of a given well. Assuming 8 laterals of a length 10-80 feet each the production rate of a well can be increased up to 280% (Figure 8.).

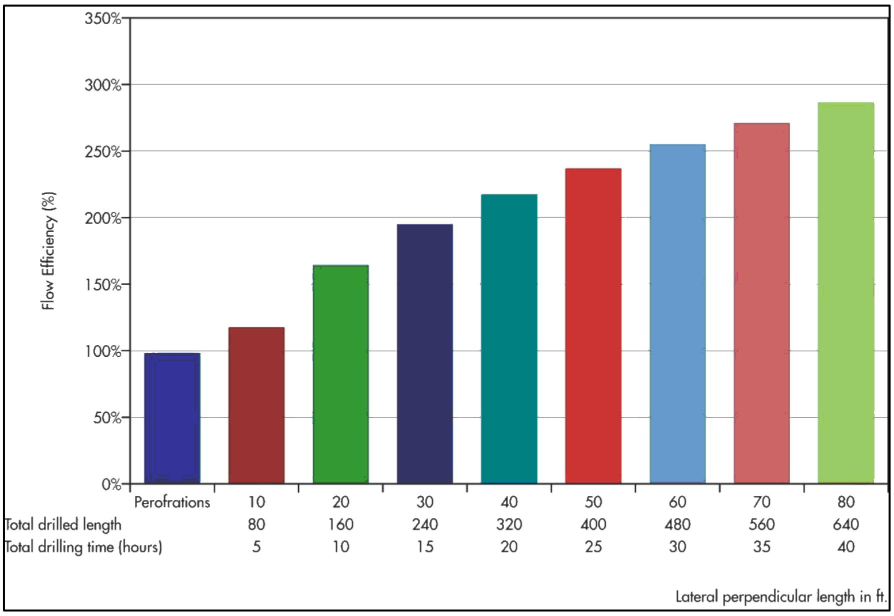


**Figure 8. Calculated Productivity Increase of a Well Due to Laser Drilled Laterals Compared to Jet Perforation (Bellarby, 2011)**

## CONCLUSIONS

The pilot laser drilling head has been built and a series of laboratory investigations have been completed. Measurements indicate that laser drilling will help save reservoir integrity and will increase productivity due to the fact that it has no harmful effect on permeability but has significant advantages hydraulically in the near well environment.

In geothermal well completion and rework laser drilling offers distinct advantages. It is a non-mechanical way to drill which is easily steerable and controlleable, ready for integration into coiled tubing systems.

The laser head uses nitrogen to displace all fluids during the drilling process. This will prevent the formation from being contaminated by drilling mud and will facilitate unimpeded fluid flow through the borehole. The technology is especially suitable for reinjection wells in porous formations as the highly porous glass will serve as a filter and will also prevent the flowing fluids from ripping off particles from the borehole wall.

## REFERENCE

Bellarby, J.: Well Completion Design, *Elsevier*, ISBN: 978-0-444-53210-7 (2009), 378-390.

Bellarby, J.: Laser Drilling of Laterals. *A Feasibility Report*. August (2011).

Bódi, T: Report on Petrophysical Properties and Permeability Changes of Laser Treated Reservoir Rocks, *Research Institute of Applied Earth Sciences, University of Miskolc,* (2014)