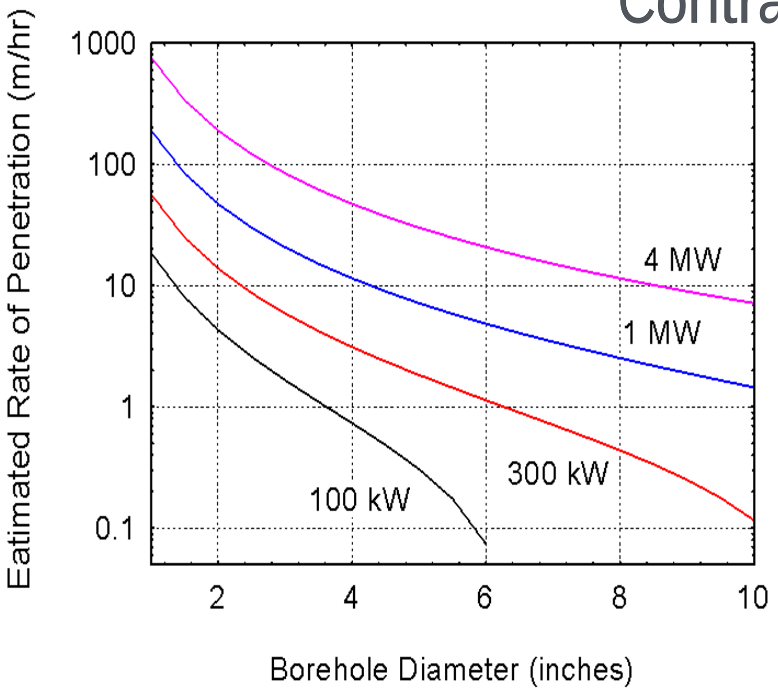
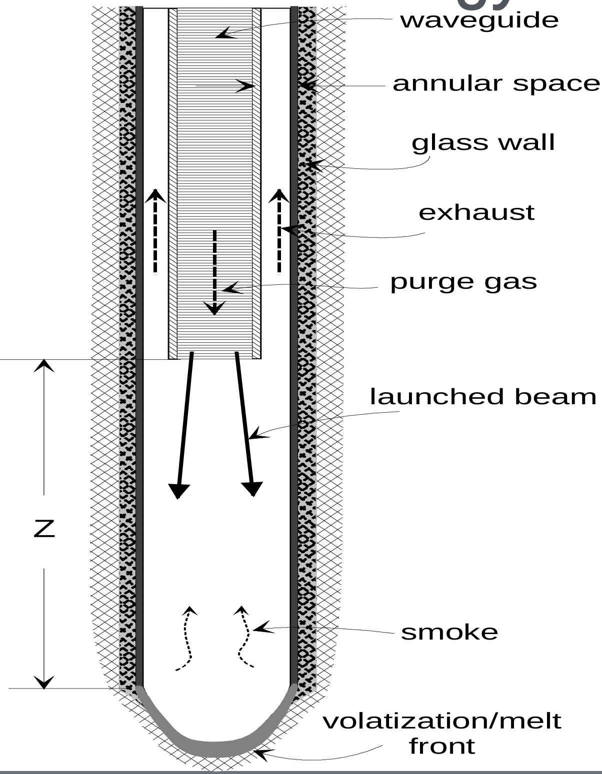
Deep Geothermal Drilling Using Millimeter Wave Technology

Contract - DE-EE0005504





MMW Drilling & Lining

Project Officers: Ava Coy & Erik Swanton

Total Project Funding: $1,093,815/ Spent: $285,998

Presented on: April 24, 2013

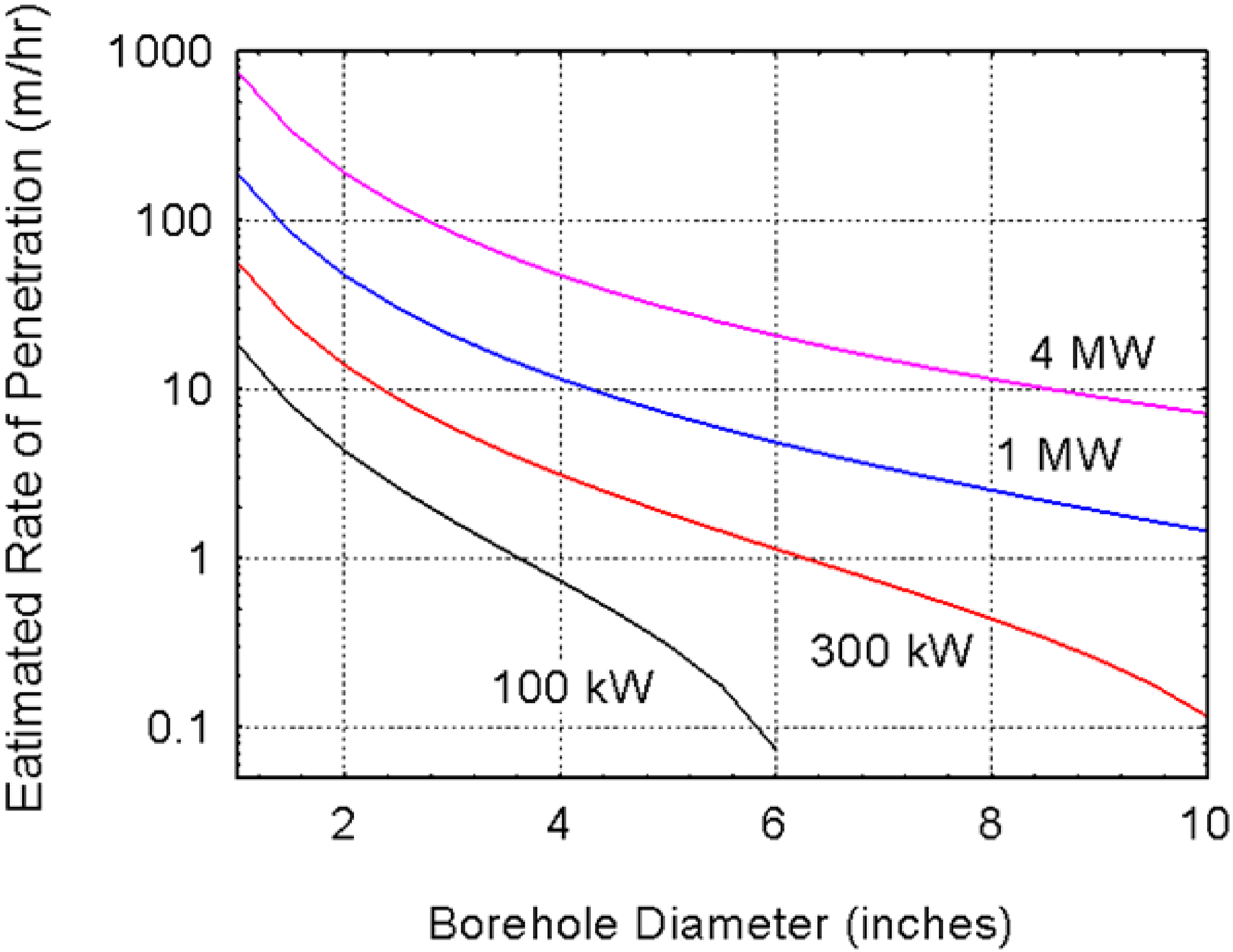
PI & Presenter: Ken Oglesby
Impact Technologies LLC
SubRecipient: MIT- Dr.Woskov, Dr.Einstein

Research & Development Track

Relevance/Impact of Research

- Overall Objective : Further develop millimeter wave (MMW) radiation technology for drilling and lining/casing wellbores- by the melting and ablation / vaporization of rocks.
- Challenges: New technology for a difficult application
  - MMW never used on reflective materials, e.g. rocks
  - No understanding of transmission fluids above ambient conditions
  - No understanding of MMW generated rock melt as a sealing liner
  - Water impact on MMW power
  - No understanding of drilling systems needed for MMW drilling
- Impact: MMW can potentially reduce EGS well costs by-
  - Efficiently drill (at 3X rates) and line the wellbore while drilling
  - Create mono-bore primary wells from surface to EGS depth TDs
  - Directional and microbore capabilities for improved heat mining

MMW ROP for Power & Hole Diameter



Scientific/Technical Approach

- MMW for drilling and lining bores is a *blank slate*.
- Task 1- Build and bench test a full MMW system (including isolators, wave guides and mode converters) that can melt rocks. This tests the efficiency of MMW power to melt/vaporize rocks using a low powered 10 kW, 28 GHz gyrotron (only one available) to estimate the impact of 1+ MW,110GHz gyrotron at commercial power.
- Task 2- Compression test MMW rock melts to study their strength and properties in forming a sealing liner.
- Task 3- Evaluate the above tests and compare to theoretical.
- Task 4-Consider other key elements of MMW drilling / lining as full systems, not just components.
- Task 5- Design and test key components of a MMW system.

Accomplishments, Results and Progress

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1. **Designed, Built and Tested** (at 2/3 full power) the 10 kilowatt, 28 GHz gyrotron, waveguide assembly, reflected power isolator and measurement system.
2. **Designed and Tested a** new isolator for reflected power protection- Dr. Woskov presenting a technical paper to IEEE in June 2013.
3. **Design & build** (ongoing) a chamber to test various potential gases for transmission efficiency up to 500ºF and 5000 psig.
4. **Brainstorming meeting(s)** produced *preliminary* findings for an MMW drilling/ lining system -

- Goal is minimum of 1 Megawatt for commercial systems.
- Casing/Lining while MMW drilling or post-drilling lining (any drilling method) may be performed.

Accomplishments,Results & Progress- 2

- During MMW drilling –Must use an overbalanced pressurized transmission fluid system to prevent heated water/fluids (water)/ hot rock particles/ melts/ vapors from entering wellbore and annulus.
- An over-pressured system may also help (with thermal cracking) create a sealing rock melt liner while drilling.
- An over-pressured system eliminates need to cool and circulate to the surface those reduced rock and fluids.
- Three MMW drilling methods exists - fixed or constant stand-off distance from waveguide end to the rock face; variable stand-off; and a combination method (including constant rate advancement).

Accomplishments,Results & Progress - 3

- Identified the need to better understand-
  - influence of the waveguide and imperfections (bends, ovality, ID restrictions, etc…) in both pipe and borehole.
  - measurement responses (GHz to THz frequencies) from various rocks, fluids, errant MMW beams etc….
  - thermal cracking (also combined with hydraulic / pneumatic fracturing) for rock /fluid disposal.
  - heat/ energy balance of the downhole system.
  - open wellbore dynamics -heating events/locations, particle vectors and velocities by diameters/density, and rock vapor/ water/ steam plume.

4. Data Sharing- Isolator design, Transmission Gas test design

10 kW, 28 GHz CPI HeatWave Gyrotron

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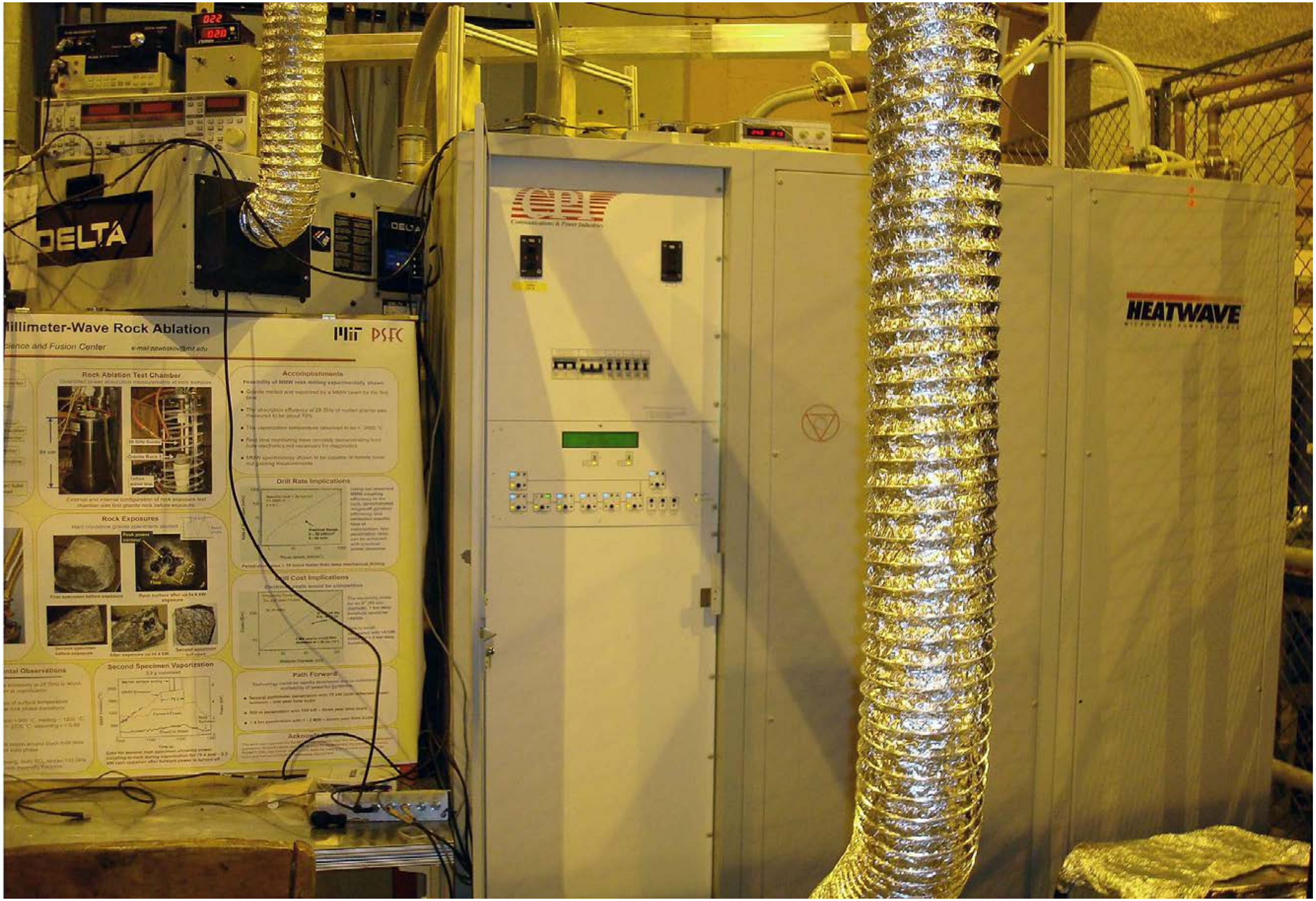

New Transmission Line Layout

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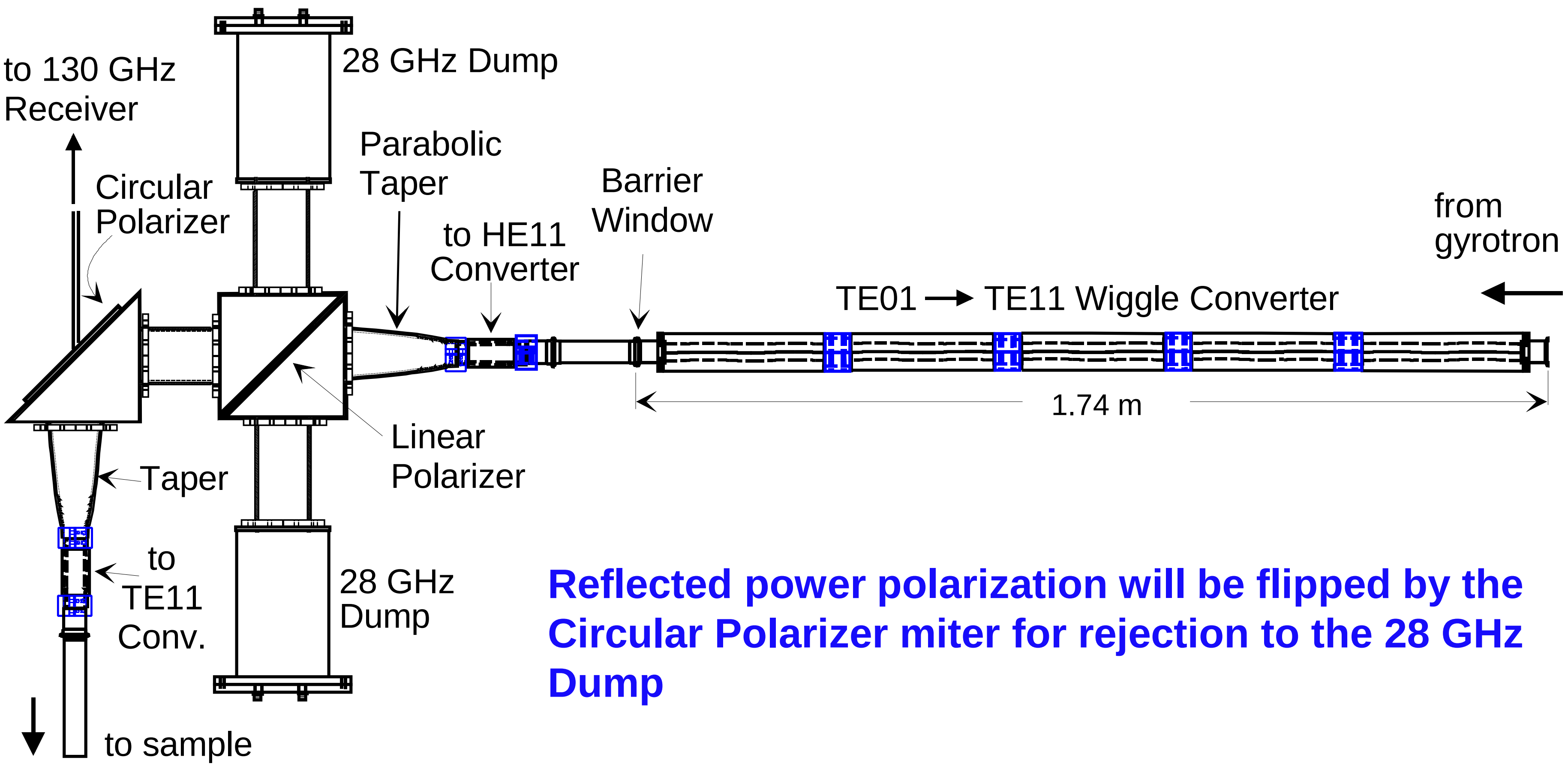

Reflected power polarization will be flipped by the Circular Polarizer miter for rejection to the 28 GHz Dump

Other MMW Bench Test Equipment

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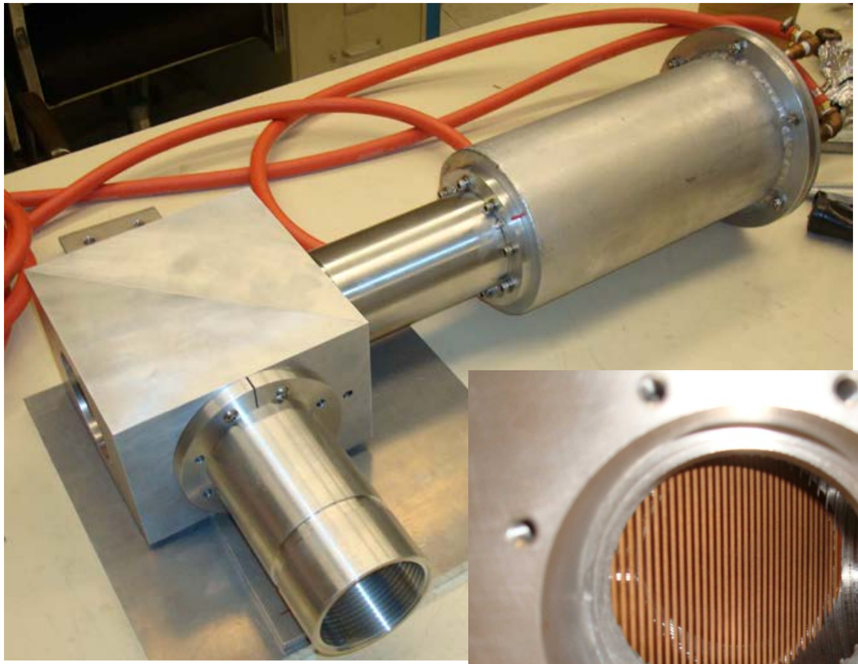
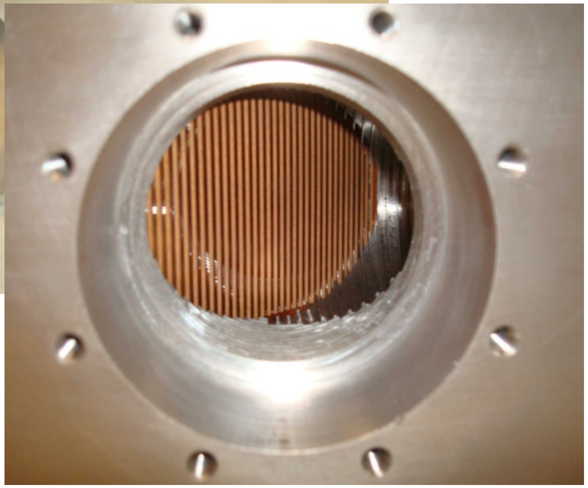
Large Miter Bend

Polarized Cross w/ Reflected Power Dump





Copper Grill Polarizer in Cross

Wiggle Converter to Linearly Polarize Beam

Ceramic (Mullite) Melt Testing

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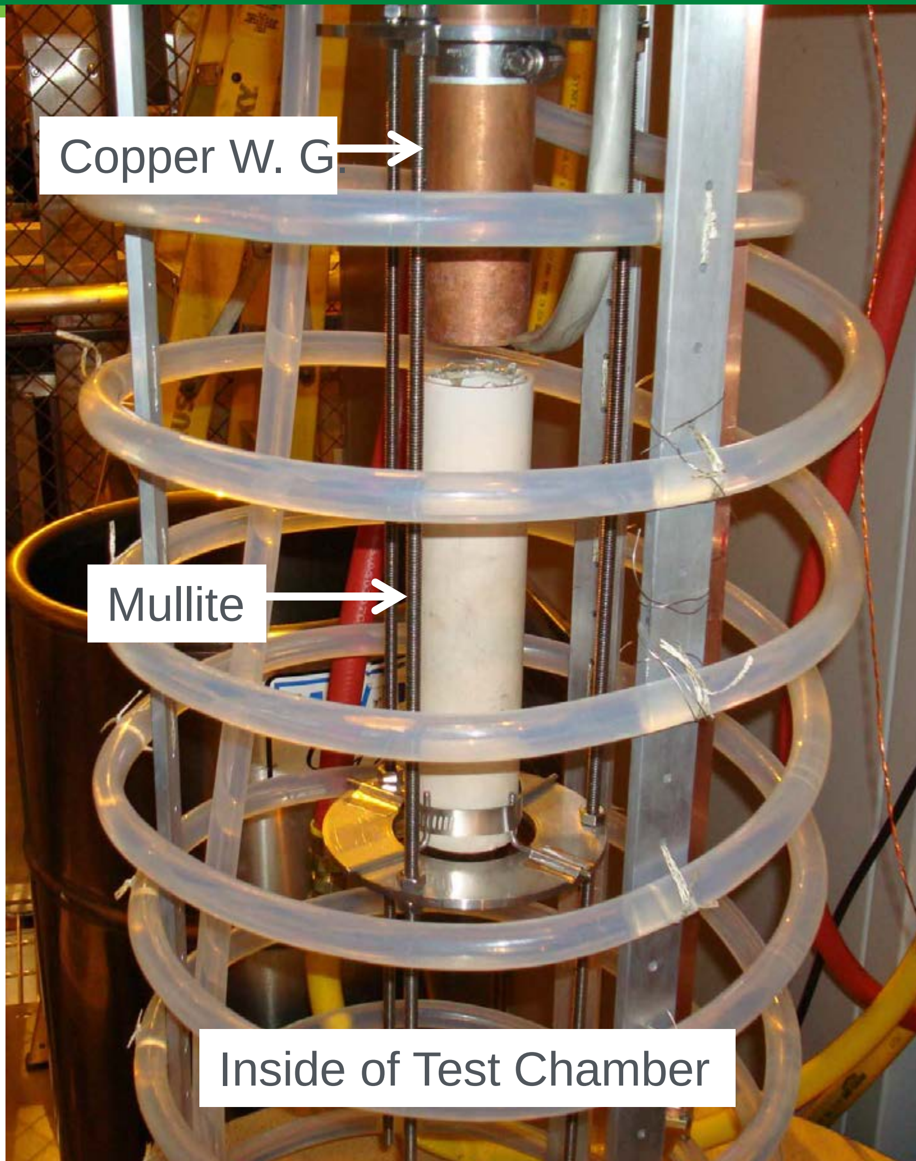
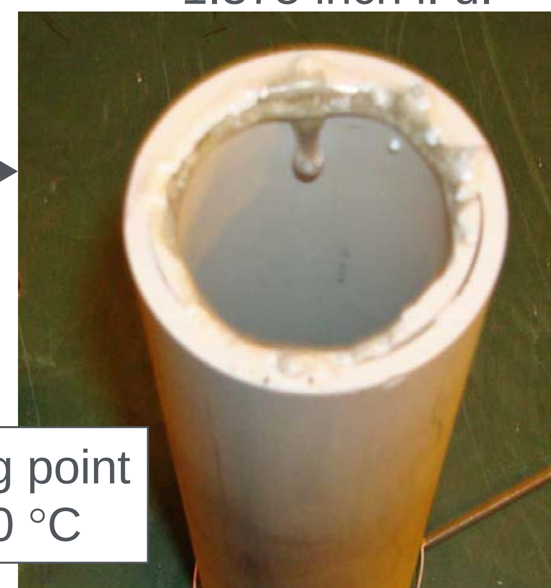


Before

1.375 inch i. d.

After



Melting point
1850 °C

Mullite Testing on MMW Bench

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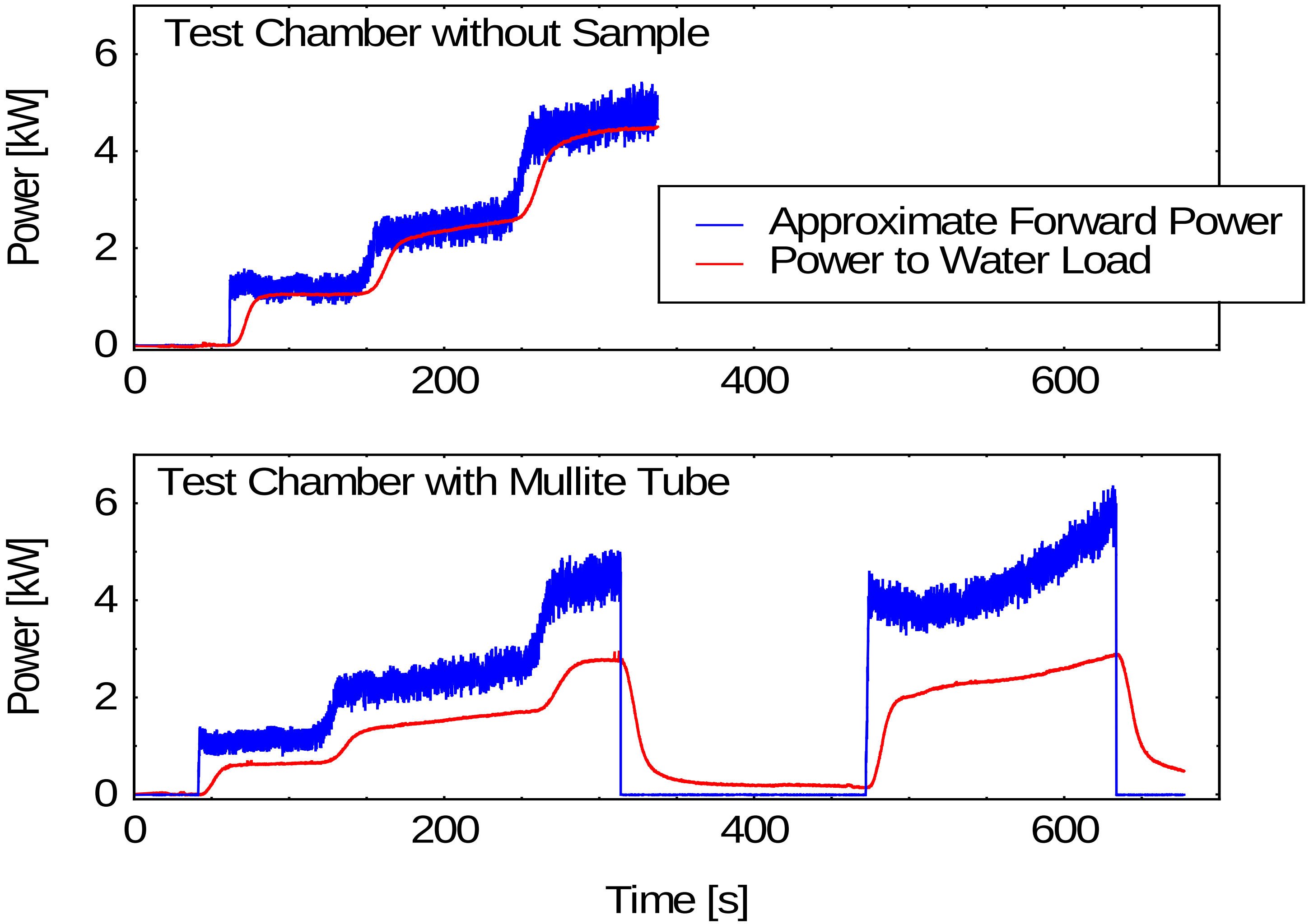
Difference in Water Load Power Indicates Power Taken up by Mullite



Rock Mechanics Bench Test Layout

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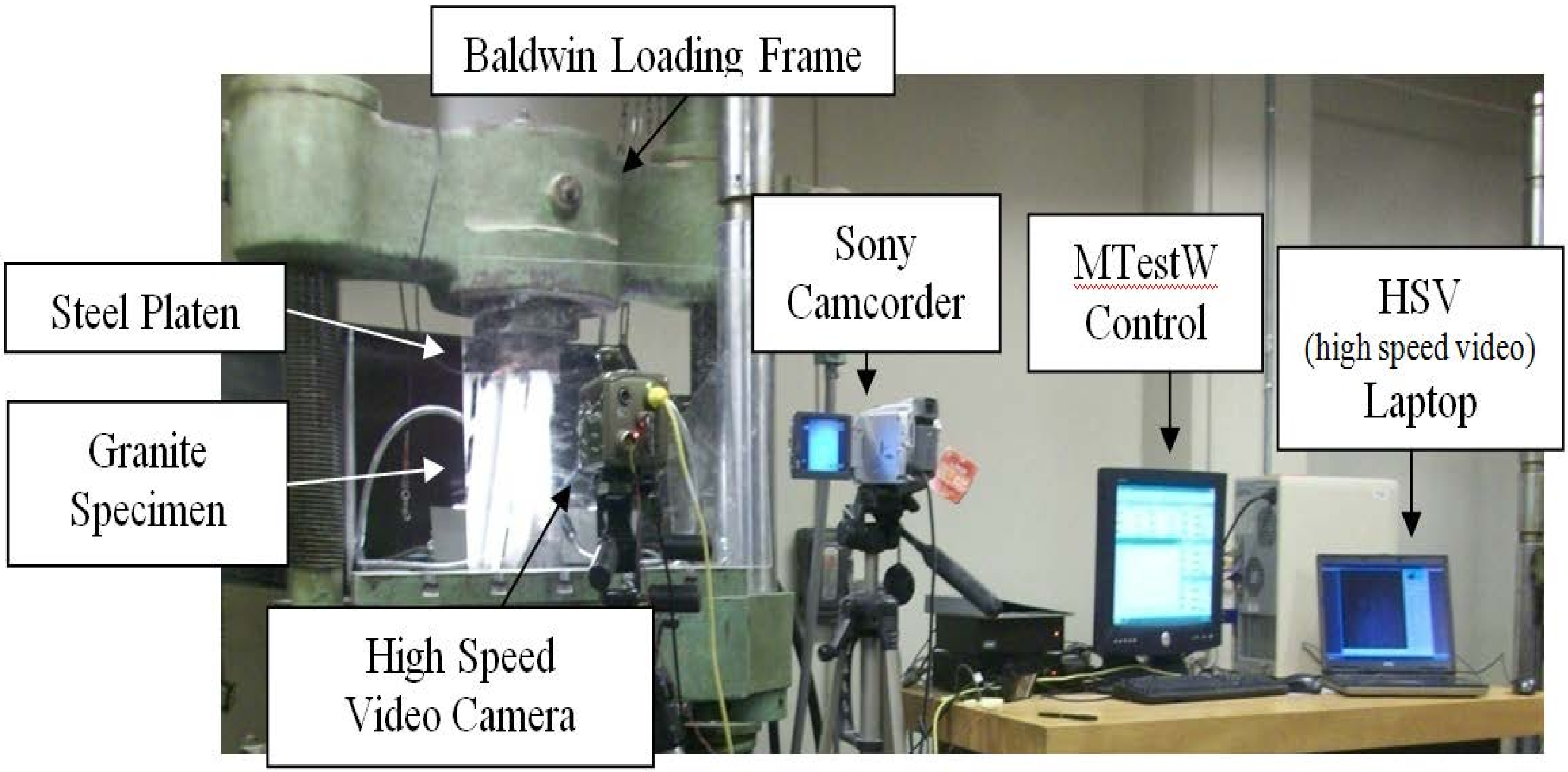

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Future Directions

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1) Finish fabrication and test 10 kW, 28 GHz bench test system
2) Perform bench testing of MMW melting and vaporization for power, efficiency and influence of key variables
3) Perform compression bench testing of MMW (and oven) generated rock melt for strength, sealing capabilities & other properties
4) Finish design and fabrication of transmission fluid test chamber and test various potential gases up to 500°F and 5000 psig.
5) Compare theoretical results with actual laboratory results
6) From above, reconsider design of drilling rig/ system for MMW Feasibility Report for technology status and future research needs

Post-Project (with funding)

8) Find higher powered 100+ kW, 110 GHz gyrotron (General Atomics, etc.)
9) Perform high powered bench testing to verify low power project findings
10) Perform shallow test drill of a microhole with mobile MMW system

Summary of MMW Drilling & Lining

1) MMW has greater cost savings potential than microwave, lasers and conventional systems for EGS / geothermal.
2) MMW may significantly lower well costs with simplified and efficient surface power generation, wave propagation, downhole assemblies/tools that do not wear and CT capabilities. Also 3+X ROP increase in hard, hot rocks.
3) MMW systems can potentially ‘case-while-drilling’ using rock melt or can post-drill install rock melt liners for significant well cost savings over steel casing and cement.
4) MMW systems have mono-bore capabilities for further savings.
5) MMW may require over-pressured drilling systems.
6) Much more research needed for a MMW prototype system

Project Management

Task No.	Task Description	Budget $	Responsibility Primary	Responsibility Support	Years-Quarters into Project 1-1	1-2	1-3	1-4	2-1
0	Project Management Plan (PMP)	$ 75,000	IMP	MIT				***********	
1	MMW Bench Testing	$ 430,000	MIT	IMP			**********		
2	Evaluation of Rock Specimens	$ 240,000	MIT	IMP	***********				
3	Evaluate Experimental Results	$ 50,000	IMP	MIT					
4	Design Key Drilling Components & System	$ 138,815	IMP	MIT			*************		
5	Prototype and Test Drilling Components	$ 110,000	IMP	MIT					
6	Feasibility Study of MMW	$ 50,000	IMP	MIT					
Total Project		$ 1,093,815							

********* indicates current status level

Planned Start Date	Planned End Date	Actual Start Date	Current End Date
30 Sept 2011	30 June 2013	23 March 2012	Same***note below

***Will request no-cost time extension to end of Summer 2013

Federal Share	Cost Share	Planned Expenses to Date	Actual Expenses to Date	Value of Work Completed to Date	Funding needed to Complete Work
$1,000,000	$93,815	$875,000	$286,000	$400,000	$807,805