Laser Ignition a New Concept to Use and Increase the Potentials of the Gas Engines

Dr. Günther Herdin/CTO GEJenbacher
2nd Annual Advanced Stationary Reciprocating Engines Conference
Future Ignition Systems

- Plasma Ignition
- High Frequency Ignition
- Auto Ignition
- Laser Ignition
- Pressure Wave Ignition
- Diesel Pilot Ignition
- ....
# GEJ Laser Ignition Activities

<table>
<thead>
<tr>
<th></th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>basic works and verification</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TU Wien, Institut for Photonics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TU Graz, Institut for ICE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>jubiläums Fonds der österreichischen Nationalbank</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>basic engineering and engine tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TU Wien, Institut for Photonics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TU Graz, Institut for ICE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>August 2000 first engine test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>basic engineering and HCCI combustion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TU Wien, Institut for Photonics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TU Graz, Institut for ICE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Francesconi Technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A3 BMVIT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Why Laser Ignition?

conventional spark plug systems comes to the physical border line

……… and the Laser ignition can help to have BMEP`s higher than 2.4 MPa for gas engines. With this we see efficiencies of 48 % possible and NOx emissions in the range of 30 ppm.
Increase of Spark Voltage
Comparison BMEP 2.2 / 1.7 MPa

spark voltage [kV]

BMEP 2.2 MPa

BMEP 1.7 MPa

test duration [h]
Spark Voltage vs BMEP

![Graph showing the relationship between spark voltage and BMEP with two curves for different NOx emissions.]

- Blue curve: 250 mg NOx/Nm³
- Red curve: 500 mg NOx/Nm³

spark voltage [kV] vs BMEP [MPa]
Control of the Nd-Yak Laser
IC-900 E01
Scheme Research Engine

- intercooler
- throttle
- deltec tec jet
- NO$_x$, CO, H$_x$C$_y$
- exhaust
- gas
- booster
- air
- alternator
Laser – Ignition Engine Test

first engine test 08.2000
Laser - Ignition Engine Test
Potentials $\text{NO}_X$-Emissions

![Bar chart showing NOX emissions for different ignition methods.]

- Direct ignition: 250 mg/Nm³
- Pre chamber ignition: 190 mg/Nm³
- Spark ignition (laser ignition): 70 mg/Nm³
- Diesel pilot ignition: 240 mg/Nm³
- Direct ignition (second entry): 330 mg/Nm³
Comparison NO\textsubscript{X} Emission
Conventional Ignition / Laser Ignition

\begin{figure}
\centering
\includegraphics[width=\textwidth]{chart}
\caption{Comparison of NO\textsubscript{X} emissions between conventional ignition and laser ignition.}
\end{figure}
Effect of Ignition System
NO$_X$-Emission and Fuel Economy

source: SAE 780329 J. D. Dale
Pressure Course Nd-YAG-Laser
Minimum Ignition Energy, \( p_{rel} = 0.4 \text{ MPa} \)
Min. Ignition Energy Nd-YAG-Laser

- minimum ignition energy [mJ]
- rel. pressure [MPa]

Graph showing the relationship between minimum ignition energy and relative pressure.
Laser Ignition
Heat Release Position

\[ \text{dQB [%/\degree CA]} \]

\[ \text{crank angle [CA°]} \]

ROHR laser ignition
ROHR spark ignition
Laser Ignition Single Point / Multi Point

Flame front 29° after ignition

- Single point ignition
- Multi point ignition (4 points)
Laser Ignition
Heat Release - Single Point / Multi Point

\[ dQB \text{ [\%/°CA]} \]

- ROHR laser
- Multi point ignition
- ROHR spark ignition

Crank angle [CA°]
Minimum Ignition Energy - U. Maas/B. Lewis

![Graph showing minimum ignition energy for different fuels](image)

- **Propane** curve
- **Methane** curve
- **H₂** curve

- **Ignition energy [mJ]** axis
- **A/F-ratio** axis

- **2.7 current limit in the combustion vessel**
View of the Plasma after the Planar-Konvex Lens
Close 3-Point Ignition
Diffractive Lens

laser beam

6mm
diffractive lens
Diffractive Lensto Gen. 3 Ignition Plasmas
Comparison Hydrogen vs. Methane

\[ p \text{ [MPa]} \]

\[ t \text{ [ms]} \]

\[ \lambda = 1.8 \]
\[ p = 1 \text{ MPa} \]
\[ T = 200^\circ C \]

\[ H_2 \text{ MPE} = 2.43 \text{mJ} \]

\[ \text{methane MPE} = 6.33 \text{mJ} \]
Laser Optimization Combustion Vessel

min. ignition energy [mJ]

rel. pressure [MPa]

first generation

optimized laser beam

present pilot system
Self Cleaning Effect of the Window
Laser Ignition – LIF/OH Analysis

Prof. Neger TU-Graz
Example of Intensity
Energy 10 mJ/Pulse 10 ns

Rasterung:
39.6 µm horizontal
37.2 µm vertikal

- $7 \times 10^{10}$ W/cm²
- $6 \times 10^{10}$ W/cm²
- $5 \times 10^{10}$ W/cm²
- $4 \times 10^{10}$ W/cm²
- $3 \times 10^{10}$ W/cm²
- $2 \times 10^{10}$ W/cm²
- $1 \times 10^{10}$ W/cm²
Combustion Vessel Influence Temperature

(A/F-ratio=const, p=3MPa, pulse duration = 5ns)
MPE vs A/F-Ratio $\lambda$ at 30 bar
Prototype of the Special Designed Laser
Test Arrangement TU Vienna
Results of the First Spec. Designed Laser

- **COV von \( p_{mi} \) [%]**
- **spez. ind. Verbrauch [g/kWh]**
- **spez. ind. Emissionen [g/kWh]**
- **Lambda [-]**
- **COV von \( p_{mi} \) [%]**
- **Apmax, ZW, Energieumsatzpunkte [°KWnZOT]**
- **Brenndauer [°KW]**
- **Tabg [°C]**
- **ISHC**
- **ISNOx**
- **TAbg**
- **Brennd**
- **Apmx**
- **MBF5%**
- **MBF50%**
- **MBF90%**
- **ZW**
- **n = 2000 [min⁻¹]; \( p_{mi} = 4 \) [bar]; homogen; w/o AGR**

GE Jenbacher
Dr. Günther Herdin
22/03/2005
Reduction of the Ignition Delay w. L.I.

engine: Hatz 0.4 l/cyl.
Basic Concept Laser Ignition
City lights made from GE Jenbacher Gas Engines

Thank you for attention