Dr. Georg Korn
Co-Founder & CTO
Marvel Fusion

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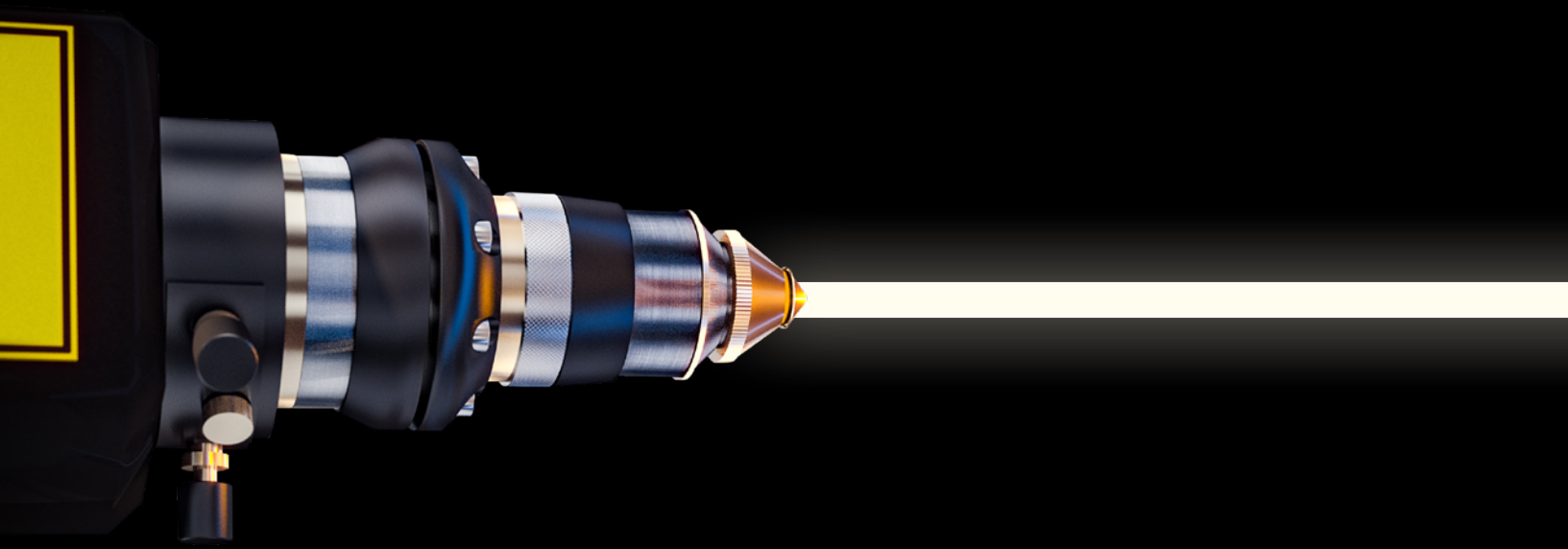


Ultrashort Pulse High Intensity Lasers: A Key Tool in Combating Climate Change

New scientific breakthroughs in laser technology have made it possible, for the first time, to develop a sustainable, safe and clean energy source that will play a crucial role in the shift towards alternative energy solutions.

The energy turnaround is already beginning to take its effect: Only 51 percent of Germany's electricity is still generated from coal, gas or nuclear power. This significant reduction indicates the strong political will to reduce the proportion of fossil fuels for environmental protection and safety reasons. The EU has once again upped its climate change targets, and the US re-entered the Paris Agreement – both factors demonstrate a strong commitment to this common goal.

At the same time, energy demand around the world is growing significantly. It's expected that the global energy requirements will have more than tripled by 2050 to 60 terrawatts compared to today. Not even half of this volume will come from renewable sources. And the conversion of highly energy-intensive industries such as manufacturing, chemical and steel production to carbon-free power has not yet been factored in.

On a global scale, solar, wind and hydroelectric power can only meet a fraction of the demand in many regions at this stage. We need a new source of energy to meet the growing demand for carbon-free energy around the clock at competitive prices.

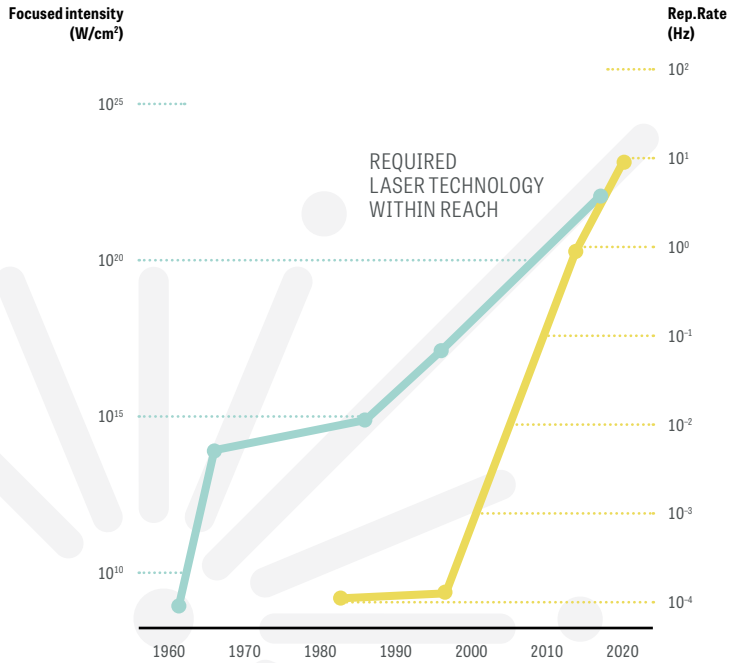
Laser technology could be the key.

New scientific breakthroughs make it possible to adapt the promising technology from laboratories for commercial use, overcoming previous challenges associated with alternative forms of energy: weather-related fluctuations causing underproduction or overproduction, risks related to costs and grid stability, long distances between production and consumption locations, as well as the insufficient expansion of power lines and high land use for wind turbines and solar panels.

Laser technology has matured in a way that it can overcome these issues. Peak power, pulse duration and repetition rate of lasers have dramatically improved over the past few years. Falling prices open the door for commercial use for the first time, for example in a power plant. The fact that the Nobel Prize in Physics was awarded to three laser researchers in 2018 demonstrates the momentum in this area of research.

"Chirped Pulse Amplification", the award-winning scientific development by Donna Strickland and Gérard Mourou, paves the way for peak laser output in the range of over 10 petawatt, opening up completely new areas of application. The continual improvement of diodes makes quick-pulse lasers with pulse repetition rates of up to 10Hz technically possible and commercially viable. Diode-pumped laser systems are more efficient than traditional pump technology using flashlamps, and they generate less heat requiring less cooling.

The breakthroughs in ultrashort pulse lasers turn the technology into the driver of progress in various fields, such as highly accurate eye surgery, diagnostics, radiation therapy, materials science and new X-ray generation methods for high resolution medical imaging.



IMPROVEMENT OF LASER TECHNOLOGY

Figure 1: Chirped Pulse Amplification enabled a new regime of focused intensity, and the continual improvement of diodes makes quick-pulse lasers with pulse repetition rates of up to 10Hz technically possible and commercially viable.

RAPID COST DECREASE IN LASER DIODES

Average price per Watt of output power ($/W)

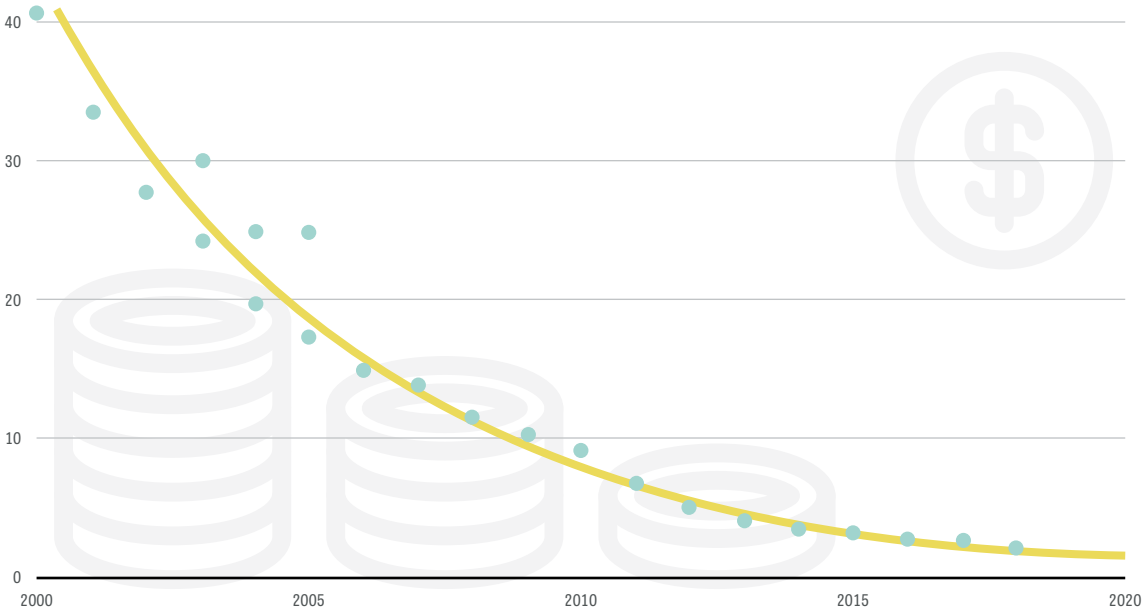


Figure 2: Diodes are based on the same semiconductor technology as photovoltaic, which is why they benefit from the same cost degression and allow for competitive electricity prices.

WE NEED A NEW SOURCE OF ENERGY TO MEET THE GROWING DEMAND FOR CARBON-FREE ENERGY AROUND THE CLOCK AT COMPETITIVE PRICES. LASER TECHNOLOGY COULD BE THE KEY.

An application that has only become possible within the last few years is laser-induced inertial confinement fusion, which could provide a carbon-free, safe, abundant, high-density, and reliable source for a constant energy supply at competitive prices – near to the metropolitan and economic centres that need it.

The technology is safe, clean and reliable: During the fusion process, fuel pellets containing hydrogen isotopes or protons and the boron-11 isotope are hit with a high intensity short pulse laser. This triggers the fusion of the fuel's nuclei – the actual inertial fusion. No neutrons are set free in the proton-boron process. Depending on the fuel, the energy released can be converted into electricity via a Carnot cycle or directly via magnetic induction.

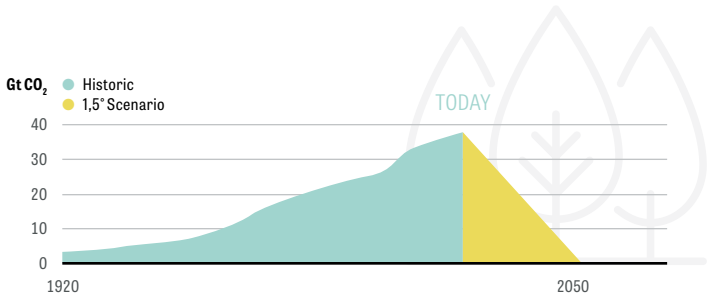
Laser-induced inertial confinement fusion provides a solution to the many challenges posed by the energy revolution and is a vital addition to alternative energies. It levels the way for a significant reduction in carbon dioxide levels, does not release hazardous emissions, and, with the right choice of fuel, just a minimal amount of activated materials and no long-lasting waste.

The provision of flexible base and peak energy in the commercial and industrial sectors could lead to new industrial growth, for example for electrification of steel production and chemical processes, for sustainable mobility (electric vehicles, synthetic aviation fuel) and for the production of green hydrogen.

The reliability of laser-induced fusion extends beyond reliability of supply. A power plant using this system can be set up for operation within a relatively short time. Its output can be adjusted from one to several gigawatts to meet prevailing demand. Most importantly, it can also be switched off within a tenth of a second when needed. In the case of unforeseen events, the reaction stops automatically when the laser stops. A chain reaction is not possible.

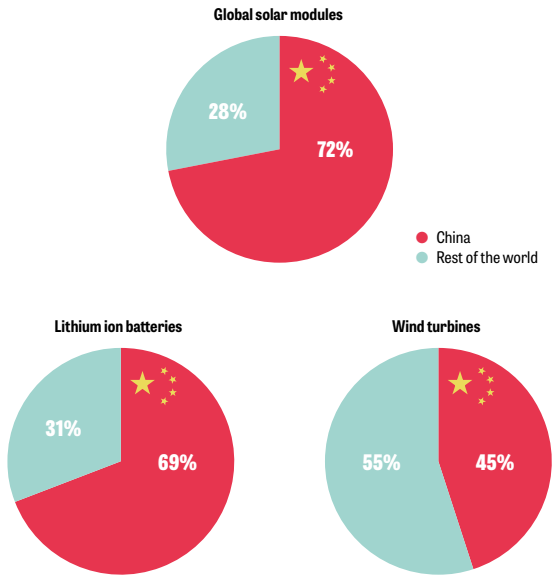
WE NEED TO ACT NOW TO REDUCE CARBON EMISSIONS IN ORDER TO MEET POLITICAL AND SOCIETAL DEMAND...

- Achieving the emissions target set in Paris Agreement
- Serve the growing global energy demand for carbon-free energy



...AND TO ALLOW EUROPE TO REGAIN GEOPOLITICAL INDEPENDENCE

- Today, Chinese firms already produce the majority of solar and wind technology globally
- They also control the refining of minerals critical to clean energy such as cobalt and lithium



Leaders globally need to invest in sovereign energy supply to
1) meet the climate goals for 2050,
2) exploit opportunities before competitors do and
3) ensure geopolitical independence.

The energy can be converted directly into electrical current, which increases the power plant's efficiency. While modern coal-fired steam power plants and lignite-fired power plants achieve an efficiency level of 46 percent and 43 percent respectively, laser-induced fusion targets an efficiency level between 50 and 80 percent.

Up until now, the limiting technology for the success of laser-initiated confinement fusion has been the intensity of the laser. With recent improvements in laser intensity in combination with the drastic increase in repetition rate, it now seems possible to generate energy at competitive prices in a commercial fusion power plant.

The great progress in laser technology, coupled with the political desire to reduce carbon emissions, has put the objective of a clean, reliable and safe energy source using modern lasers within reach for the first time.

Laser-induced inertial confinement fusion not only has the potential to meet the huge energy demands of industrialised countries, but also those of emerging and developing countries with growing populations and economies. It tackles the key issues associated with conventional and alternative energy production, thereby making a significant contribution to the energy revolution.

What's more, this new technology offers a unique opportunity for Europe to rise to the position of leader in innovative new energy technology by continuously advancing enabling technologies, such as the highly efficient diode-pumped laser, thereby preventing China and the USA from commercialising the technology first. In this way, Europe could avoid a geopolitical dependence on China for clean energy and at the same time strengthen its own industrial base.

Figure 3: Global CO_2 consumption and energy dependency