SYSTEMS AND METHODS FOR MICRO-SCALE HIGH-REPETITION RATE NUCLEAR FUSION VIA COHERENCE-CONTROLLED VACUUM SCREENING

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Abstract

A system and method for generating net fusion energy using micro-scale fuel targets driven by high-repetition-rate, low-energy optical pulses. By leveraging Recognition Science (RS) coherence control to induce vacuum polarization and screen the Coulomb barrier, the invention reduces the required confinement parameter (ρR) by approximately three orders of magnitude compared to classical inertial confinement fusion (ICF). This enables ignition of micron-scale fuel droplets (e.g., ~ 1 μm radius) using milliJoule-class lasers operating at kilohertz or megahertz frequencies. The resulting "fusion internal combustion" architecture replaces the single-shot, megajoule-scale paradigm of traditional ICF with a continuous stream of micro-explosions, enabling compact, tabletop, or room-sized fusion power generators.

1 Technical Field

The present disclosure relates to nuclear fusion energy generation, specifically to high-repetition-rate inertial confinement fusion systems utilizing coherence-controlled vacuum screening to enable micro-scale ignition.

2 Background

Traditional Inertial Confinement Fusion (ICF) relies on the thermal compression of large fuel pellets (e.g., 1-2 mm radius) to achieve ignition conditions defined by the Lawson criterion. This approach requires massive driver energy (MegaJoules), resulting in stadium-sized facilities (e.g., NIF) capable of only a few shots per day. The "single giant explosion" paradigm imposes extreme engineering constraints on chamber durability, debris management, and driver cost.

Recognition Science (RS) theory predicts that the effective Coulomb barrier between nuclei can be screened by a coherent electromagnetic field that modifies the vacuum's dielectric permittivity. This screening effect reduces the required temperature and confinement product (ρR) for ignition by factors of up to 1000x, theoretically permitting fusion in regimes previously considered impossible.

3 Summary

The invention provides a "Fusion Engine" architecture that operates on the principle of continuous micro-ignition rather than singular macro-ignition.

Core Concept

A high-frequency droplet generator delivers a stream of micron-scale fuel targets (e.g., Deuterium-Tritium or p-B11) into a reaction chamber. A synchronized, phase-coherent laser system delivers milliJoule-scale pulses with attosecond timing precision to each droplet. The coherent pulse train induces vacuum polarization, lowering the Coulomb barrier and triggering fusion at reduced temperatures (e.g., ~ 1.4 keV) and confinement scales.

Key Advantages

- **Compact Scale**: The driver energy requirement scales as R^3. Reducing target size by 1000x reduces energy by 10^9, enabling tabletop-scale drivers.
- **Continuous Power**: High repetition rate (kHz/MHz) provides steady thermal output, simplifying heat extraction and electricity generation.
- **Reduced Stress**: Micro-explosions produce manageable shock waves and debris, extending chamber life.
- **Commercial Viability**: Utilizes commercially available milliJoule lasers (with custom timing control) rather than custom MegaJoule facilities.

4 Detailed Description

4.1 Scaling Laws

The invention leverages the RS scaling law for barrier reduction: $S = 1/(1 + C_\phi + C_\sigma)$. With high coherence ($S \approx 1/3$), the effective tunneling probability increases by $\sim 1000\times$. This allows the critical confinement parameter ρR to drop from ~ 0.3 g/cm^2 (classical) to ~ 0.0003 g/cm^2 (RS). For constant density, this implies the target radius R can be reduced by $\sim 1000\times$, from millimeters to microns.

4.2 System Architecture

The system comprises:

1. **Micro-Target Injector**: A piezoelectric or microfluidic droplet generator creating a precise stream of fuel droplets (1-10 μm diameter) at high frequency (1 kHz - 1 MHz).

2. **Coherent Driver**: A pulsed laser system delivering milliJoule-class pulses. The driver incorporates the Active Coherence Control Loop (described in a separate disclosure) to ensure sub-femtosecond phase alignment with the RS ϕ-schedule.

3. **Tracking & Synchronization**: A real-time optical tracking system that locks the laser firing to the droplet position with sub-micron accuracy.

4. **Reaction Chamber**: A compact vacuum vessel (e.g., < 1 meter diameter) lined with a heat exchange medium (e.g., liquid metal curtain or flowing gas) to capture energy from the continuous micro-fusion stream.

4.3 Operating Regime

- **Fuel**: D-T, D-D, or p-B11.
- **Target Size**: 1 to 10 microns radius.
- **Pulse Energy**: 1 to 10 milliJoules.
- **Pulse Duration**: Femtosecond scale, ϕ-spaced train.
- **Repetition Rate**: 1 kHz to 1 MHz.
- **Operating Temperature**: $\sim 1 - 2$ keV (vs. > 10 keV classical).

5 Claims

1. A nuclear fusion power generation system, comprising:
   - A target delivery system configured to inject a continuous stream of fuel micro-droplets having a radius of less than 50 microns into a reaction chamber;
   - A pulsed laser driver configured to deliver optical pulses with an energy of less than 1 Joule per pulse to the micro-droplets;
   - A timing control system configured to synchronize the optical pulses with the micro-droplets with a timing jitter of less than 1 femtosecond;
   - Wherein the optical pulses are phase-modulated to induce a vacuum polarization effect that screens the Coulomb barrier within the micro-droplets, thereby enabling fusion ignition at the specified size and energy scale.

2. The system of claim 1, wherein the system operates at a repetition rate exceeding 100 Hertz.

3. The system of claim 1, wherein the fuel micro-droplets have a radius between 0.5 microns and 10 microns.

4. The system of claim 1, wherein the pulsed laser driver delivers energy in a sequence of sub-pulses spaced according to a schedule derived from the Golden Ratio (ϕ).

5. The system of claim 1, wherein the reaction chamber has a characteristic dimension of less than 2 meters.

6. A method for generating fusion energy, comprising:

   - Generating a stream of micro-scale fuel targets;
   - Irradiating each target with a phase-coherent optical pulse train having an energy less than 1 Joule;
   - Controlling the phase and timing of the pulse train to maximize vacuum dielectric permittivity at the target;
   - Repeating the irradiation at a frequency sufficient to generate continuous thermal power output.