The

Dual Fluid Reactor

A nuclear concept with high economic efficiency, integral fuel reprocessing, high-temperature chemistry, and waste management

Armin Huke[1], Götz Ruprecht[1], Daniel Weißbach[1,2], Stephan Gottlieb[1], Ahmed Hussein[1,3], Konrad Czerski[1,2]

IFK Berlin

1) Institut für Festkörper-Kernphysik gGmbH, Leistikowstr. 2, 14050 Berlin, Germany
2) Uniwersytet Szczeciński, ul. Wielkopolska 15, 70-451, Szczecin, Poland
3) University of Northern British Columbia, 3333 University Way, Prince George, BC, Canada, V6P 3S6

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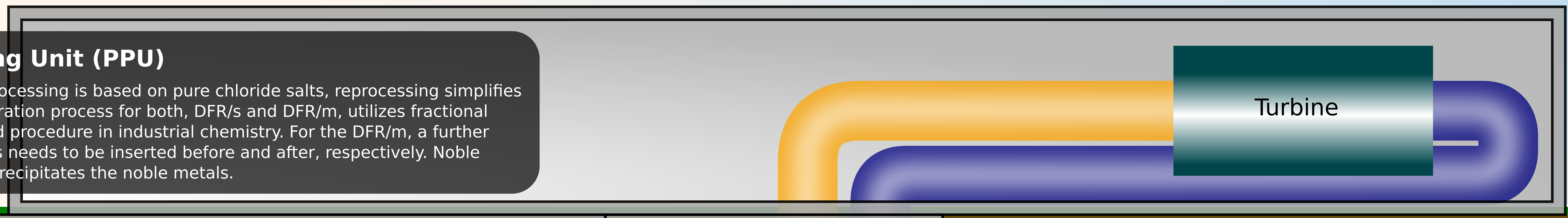
The Dual Fluid Reactor (DFR) is an innovative, high-temperature fast reactor design invented in 2011. The basic idea is the separation of the coolant from the fuel loop. This goes beyond the MSR concepts and resolves the former contradiction between high power density and inherent passive safety. It leads to a great improvement of the economic efficiency, also due to internal partitioning and transmutation, thus consuming today's LWR waste, Thorium, as well as natural and depleted Uranium.

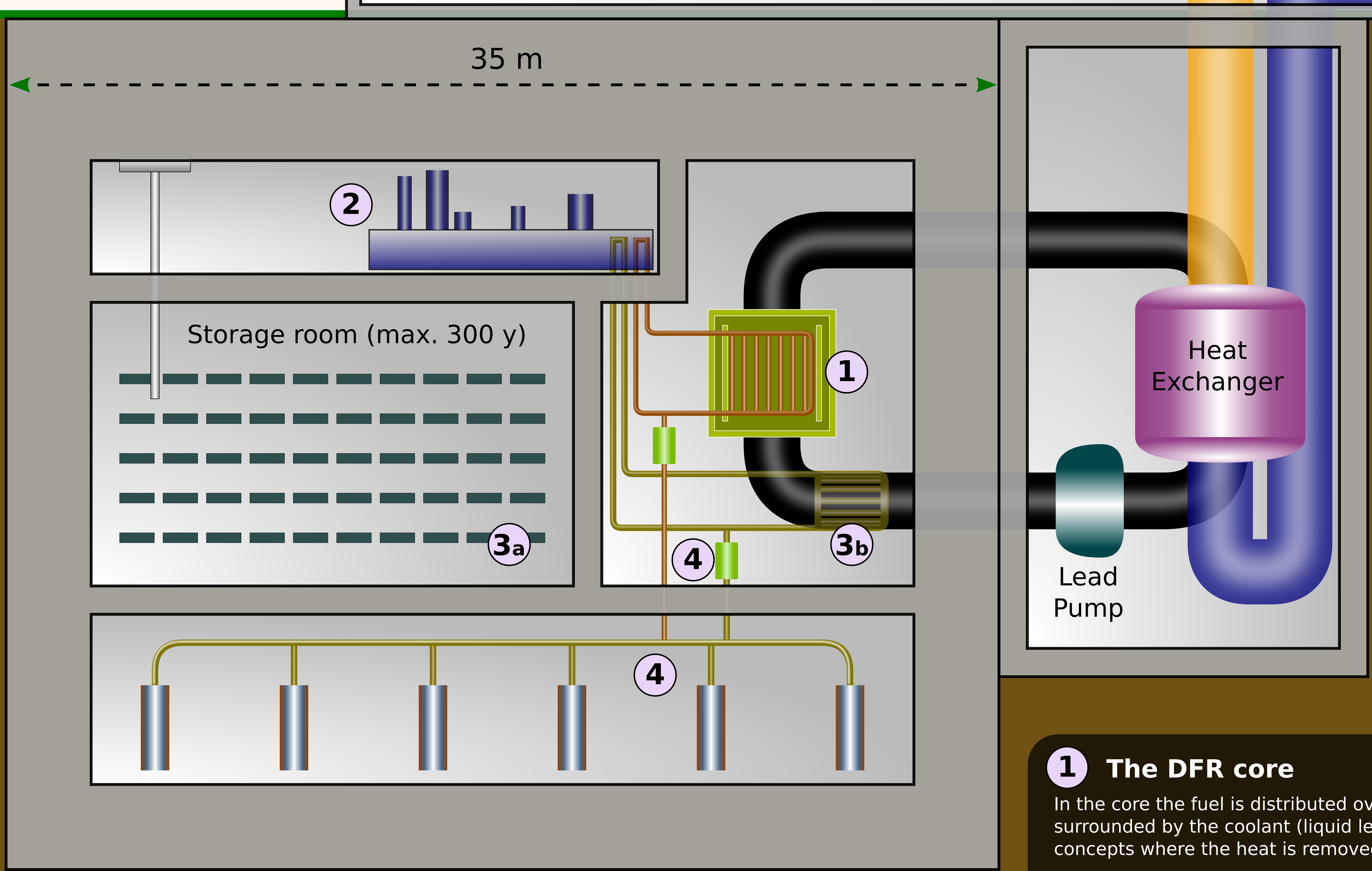
There are 2 variants of the DFR currently being developed:

- **DFR/m** with molten metal fuel
- **DFR/s** with molten salt fuel



2 The Pyroprocessing Unit (PPU)

As the fuel is undiluted and the processing is based on pure chloride salts, reprocessing simplifies remarkably. The PPU's major separation process for both, DFR/s and DFR/m, utilizes fractional distillation/rectification, a standard procedure in industrial chemistry. For the DFR/m, a further chlorination and reduction process needs to be inserted before and after, respectively. Noble gas purging removes Iodine and precipitates the noble metals.



DFR Power Plant

Shown is a 1.5 GW electrical (3.0 GW thermal) power plant.
In the core (1) the heat is transfered to the coolant (black loop), preferably pure Lead, which in turn transfers the heat to the conventional part where the preferred medium is supercritical CO_2 or water, driving the turbines (top). The nuclear part is so small that it can easily be built subterraneously. A high operating temperature of about 1000 °C ensures cheap hydrogen production for the chemical industry, automotive fuel synthesis, and water desalination. The DFR's high transmutation capability enables not only the incineration of its own long-lived remnants but also the treatment of the nuclear waste produced by today's reactors. Due to a strong negative temperature coefficient, the power plant can be controlled just by the output power demand - no control rods are necessary. High flexibility in the electricity production makes the DFR ideal for combination with other power plants in a complex electrical grid. Estimated overnight capital costs are below 1 €/W and electricity production costs are about 6 €/MWh - a factor five lower than today (see bottom of the poster).

4 Melting fuse and subcritical heat storage

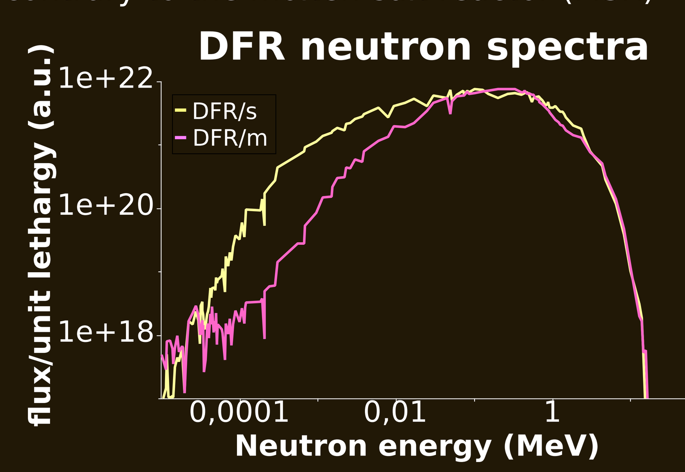
In case of desired fuel removal due to maintenance or in case of overheating, the liquid salt from the PPU, from the core, or from the actively cooled decay tank can be drained via their respective fuse plugs (green) where it is normally frozen. These plugs open passively if overheating and/or power outage occurs, the salt melts and flows into tanks by gravity inside a large subcritical heat storage.
The decay heat lowers from 100 MW to some 5 MW within 2 weeks and dissipates passively. The room is filled with material with good heat conductivity and high volumetric heat capacity, e.g. iron bricks.

1 The DFR core

In the core the fuel is distributed over 10,000 vertical tubes and becomes critical. These tubes are surrounded by the coolant (liquid lead) removing the heat, contrary to the molten-salt reactor (MSR) concepts where the heat is removed by the fuel itself.

DFR/s is already quite different from the "usual" MSR concepts. Thanks to the Dual Fluid principle, heat can be removed from the core much more efficiently, making it possible to use pure undiluted actinide chloride salts. This makes the core very compact, which in turn enables the exploitation of expensive, highly corrosion resistant materials at 1000 °C.

DFR neutron spectra



DFR/m further increases the power density and further hardens the neutron spectrum. Due to much better heat conduction of the metallic fuel, several improvements of the reactor construction could be additionally made considerably enhancing the economy. First simulations indicate conversion ratios close to 2 (most actinides with even number of neutrons become burnable).

3 Fission product storage

Although the fission products are removed from the core, they need to be cooled, depending on their activity. While processed, the short-lived fission products (half-lives from hours to several days) decay inside the PPU (2). Isotopes with half-lives up to one year need to be actively cooled and are stored in a tubular system (3b) inside the primary coolant, generating heat power of up to 20 MW.
The very long-lived ones, like Tc-99, can be transmuted in the core (1). All other fission products, put into metal capsules, decay inside a passively air-cooled storage room (3a) in a few centuries, roughly 90% of them within 100 years.

How efficient is the DFR?

The "Energy Return on Energy Investment" (EROI)

The EROI describes the efficiency of a power plant by comparing the electricity output with all the expended exergy input.

For comparison:
Wind and PV: 1-4
Fossil fuels: 30
Hydro: 35

Nuclear:
Today's LWRs: 75
Theoretical limit: 10,000

If these expenses are reduced to DFR level, EROI and costs change to...

	LWR	Enrichment	Construction and Operation	Uranium supply		Fuel cyle	Deconstruction	DFR/s	DFR/m
EROI:	75	→ 115	→ 120	→ 390		→ 1000	→ 2000		5000
Costs (cent/kWh overnight):	2.7	→ 2.3	→ 1.5	→ 1.1		→ 0.8	→ 0.65		?

From LWR to DFR. Many steps are repealed or reduced, increasing the EROI and decreasing the costs. DFR/m comes close to the theoretical limit of nuclear energy, dominated by the Uranium mining expense.

Literature

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Armin Huke
+49 160 94152262

Götz Ruprecht
+49 152 03374582

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http://dual-fluid-reactor.org