Project Hydrus and Pulsed Power at AWE

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- Others

Introduction

- The Problem
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  - The role of Pulsed Power
- Where We Are Today
  - Current Facilities and Pulsed Power
- What We Need Tomorrow
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    - Phased Delivery Approach
- Flash X-Ray Sources
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  - Electron Beam Diode Research
- Other Pulsed Power Requirements and Research
- AWE Pulsed Power Strategy

AWE, the CTBT and Weapon Certification

- **The Atomic Weapons Establishment (AWE) has been central to the defence of the United Kingdom for more than 50 years, providing and maintaining the warheads for the country's nuclear deterrent. Uniquely among the nuclear powers, AWE covers the whole life cycle of nuclear warheads, in a single establishment. This includes initial concept and design, through component manufacture and assembly, to in-service support and, finally, decommissioning and disposal.**

- **Over 5000 permanent staff**

- **Budget of over £500 million per year**

AWE Aldermaston

AWE Burghfield

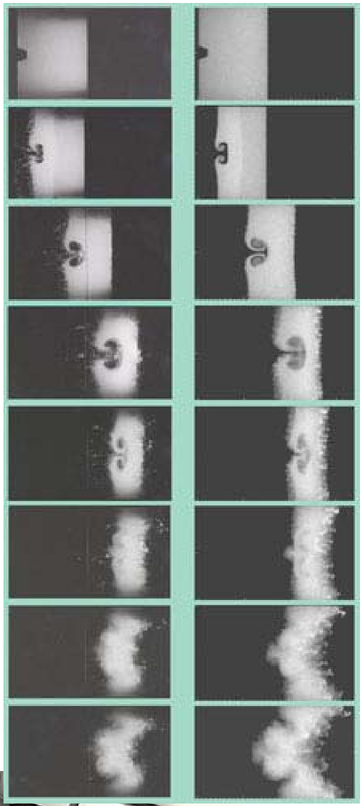
The Comprehensive Test Ban Treaty

- **Article I:**

- **Each State Party undertakes not to carry out any nuclear weapon test explosion or any other nuclear explosion, and to prohibit and prevent any such nuclear explosion at any place under its jurisdiction or control.**
- **Each State Party undertakes, furthermore, to refrain from causing, encouraging, or in any way participating in the carrying out of any nuclear weapon tests explosion or any other nuclear explosion.**

Weapon Certification

- **Without Underground Tests (UGTs), weapon certification is built upon a suite of engineering, experimental and modelling techniques**
- **When these are brought together, coupled with historical knowledge, they are enough to underwrite the nuclear deterrent**



The Role of Pulsed Power

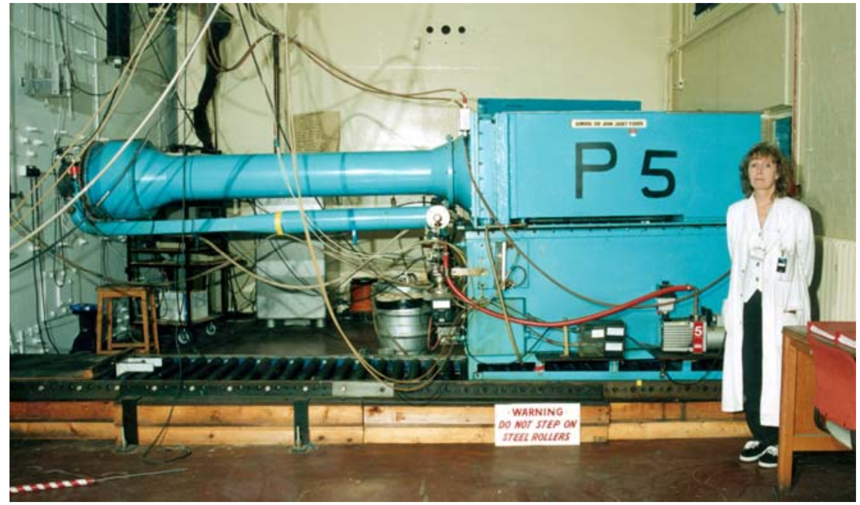
- **Hydrodynamics is the study of explosively driven systems operating at supersonic velocities involving the interaction of a wide range of materials including metals and plastics. A complete suite of diagnostic tools are applied to study the experiments including flash radiography.**
- **Flash radiography applied to weapon’s physics issues was pioneered at AWE which in part allowed the UK to minimise its reliance on UGTs before the CTBT and placed AWE well once underground testing was banned**
- **Pulsed power is also well suited to generating Hydrodynamic conditions itself, a capability amply demonstrated by machines like Z (soon to be ZR) at Sandia**

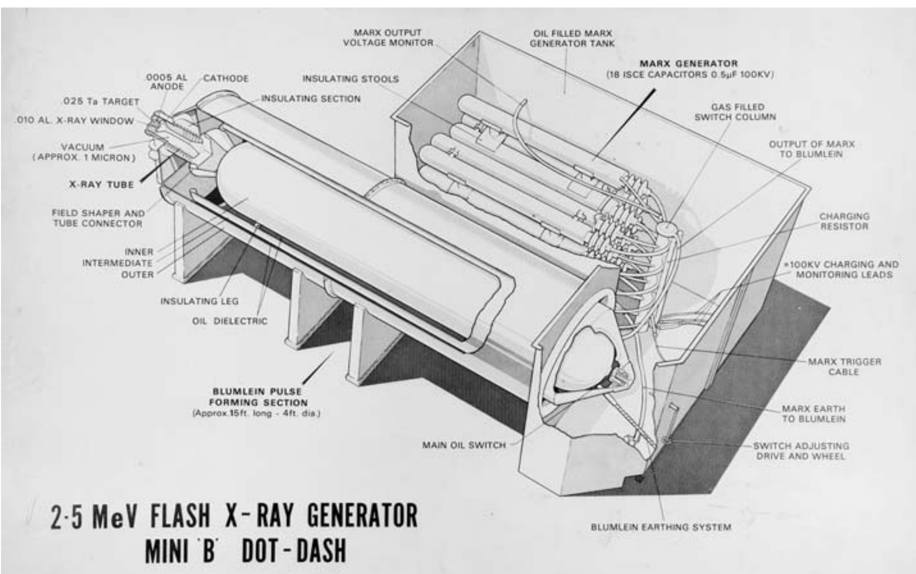
Where We Are Today

- The Pulsed Power Group within the Hydrodynamics Department under Charlie Martin has developed a unique and unrivalled suite of flash x-ray sources coupled to firing chambers
- These facilities cover the broad range of experiments needed to underwrite the weapon to those needed to perform basic hydrodynamics research
- They all provide twin x-ray pulses that can be individually timed to an accuracy of a few 10s of nanoseconds
- X-Ray pulse lengths are around 50ns to ensure that any Hydrodynamic motion is essentially frozen

Low Areal Mass Facilities

- **Mevex**
- **800keV, 1.2R 2.5mm spot**
- **Fitted in 2 firing chambers**
- **Used for ‘physics’ experiments**
- **0.25 to 4kg of TNT**

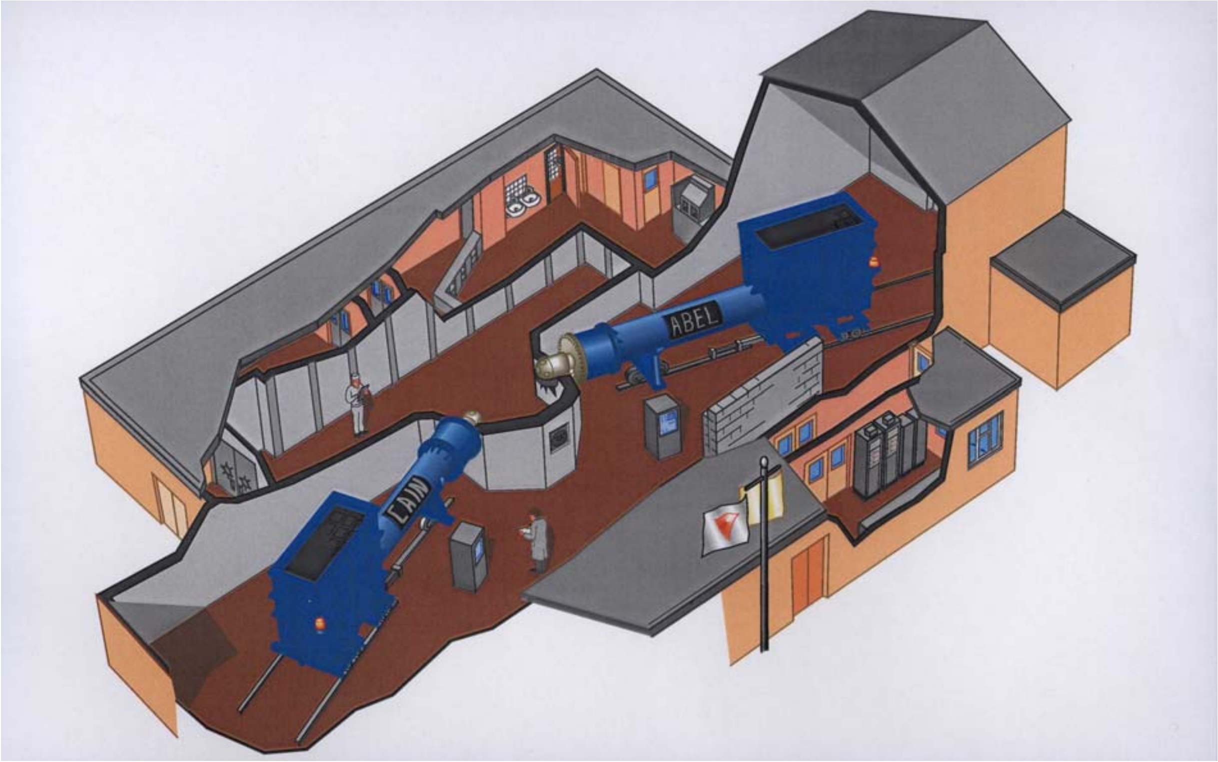




- **Mini B**
- **2.5MeV, 10R 2.5mm spot**
- **One pair, Dot and Dash are fielded on experiments requiring a large field of view**
- **4kg TNT (up to 30kg mitigated)**

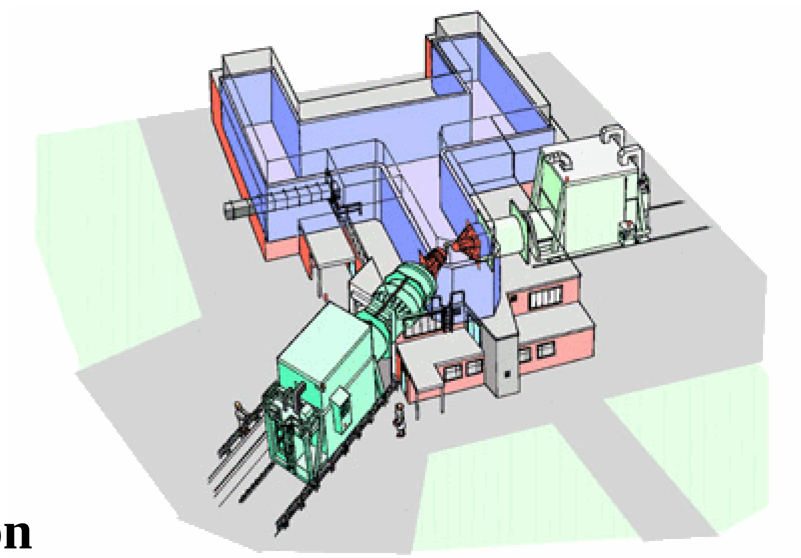
Medium Areal Mass Facility

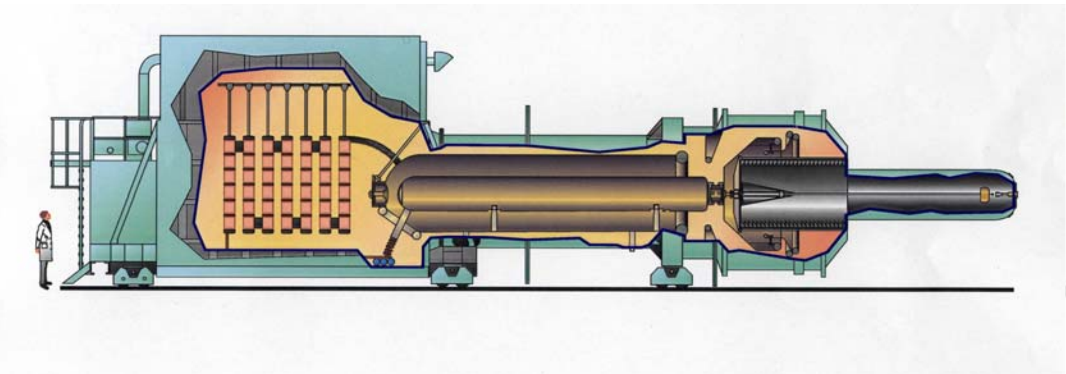
- Twin Superswarf machines, Cain and Abel
- 60R from a 3.9mm x-ray spot
- 0.5kg charge limit

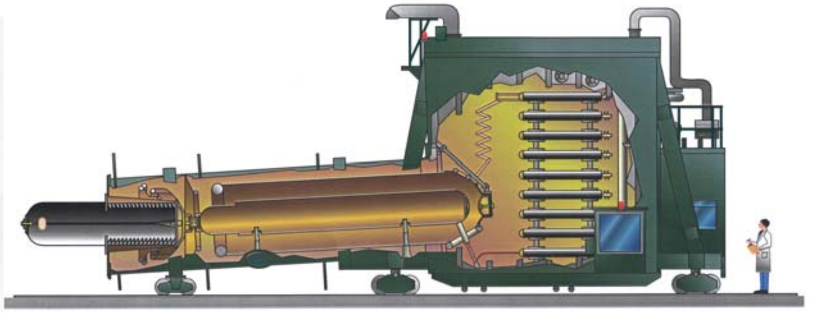


High Areal Mass Facility

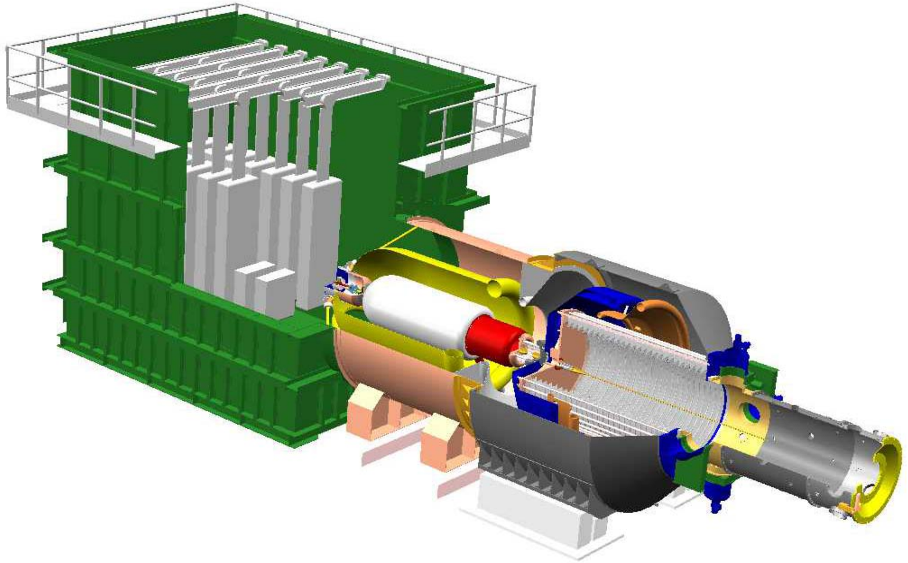
- **Twin Mogul machines**
  - **D, 160R 4.3mm spot**
  - **E, 400R 5.1mm spot**
- **4kg TNT (up to 30kg mitigated)**
- **Used for the most challenging ‘core punch experiments’**
- **Has been one of the leading facilities in the world but will soon be eclipsed when DARHT 2 becomes operational**



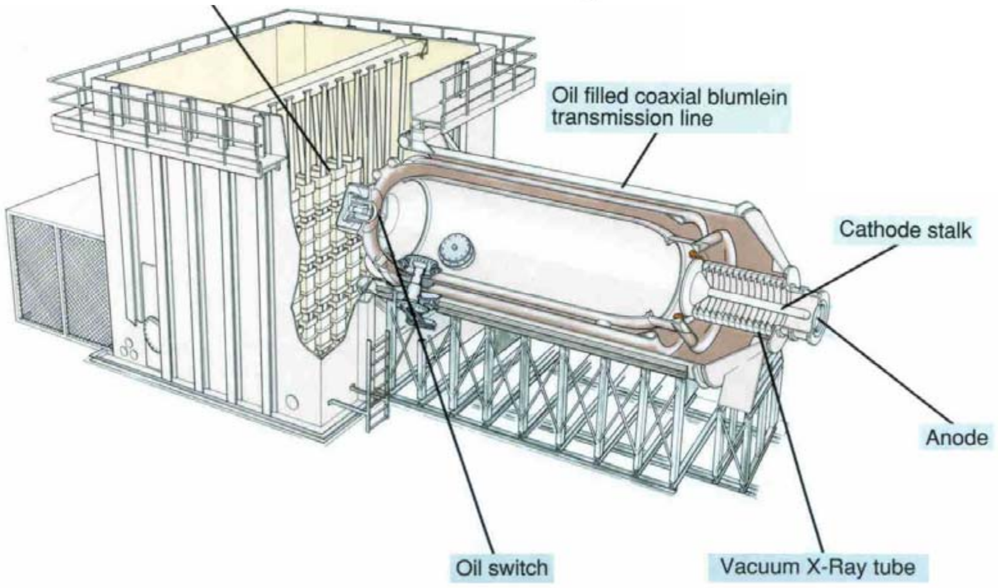


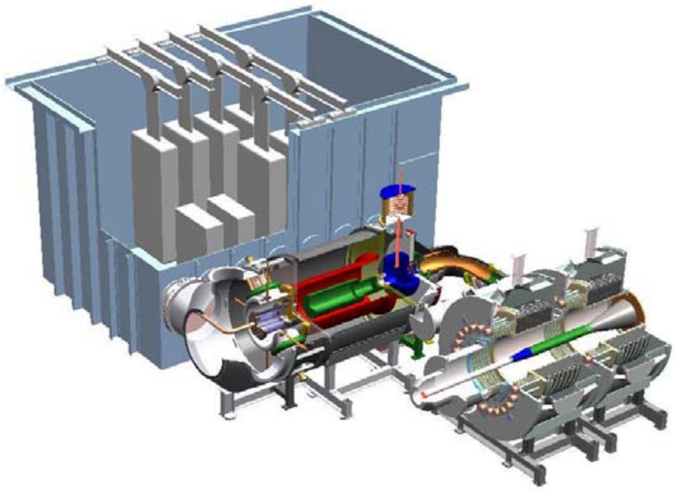


Research Machines



- All machines used for diode and diagnostic development
- EMU and PIM also used for pulsed power component research
- Eros is shared with the effects research community





What we need tomorrow

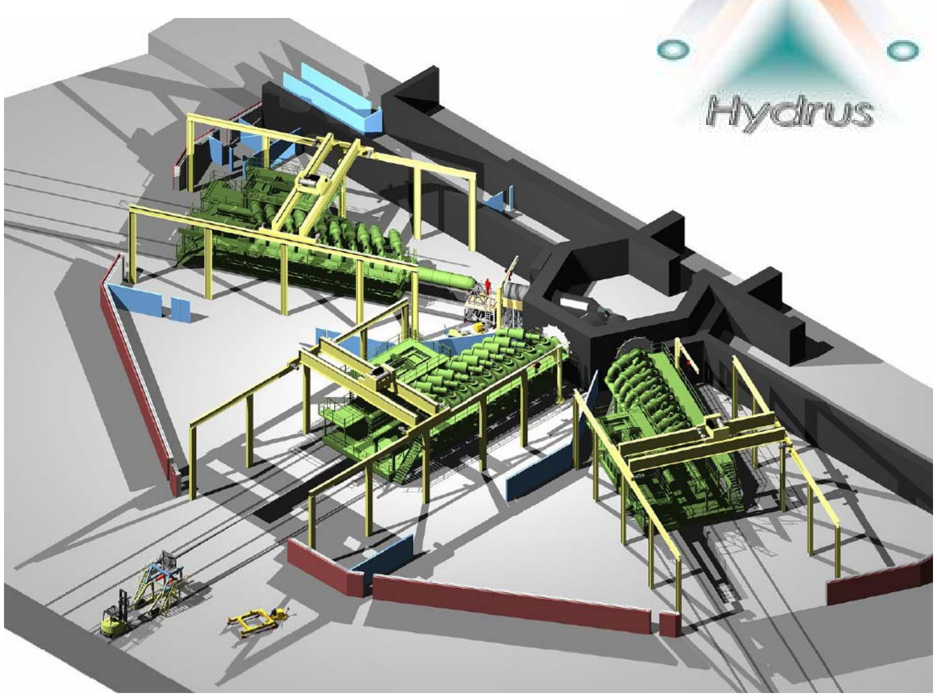
- **To continue to meet the goals of the AWE experimental trials programme we need to maintain and improve our existing facilities and also to build new more capable facilities**

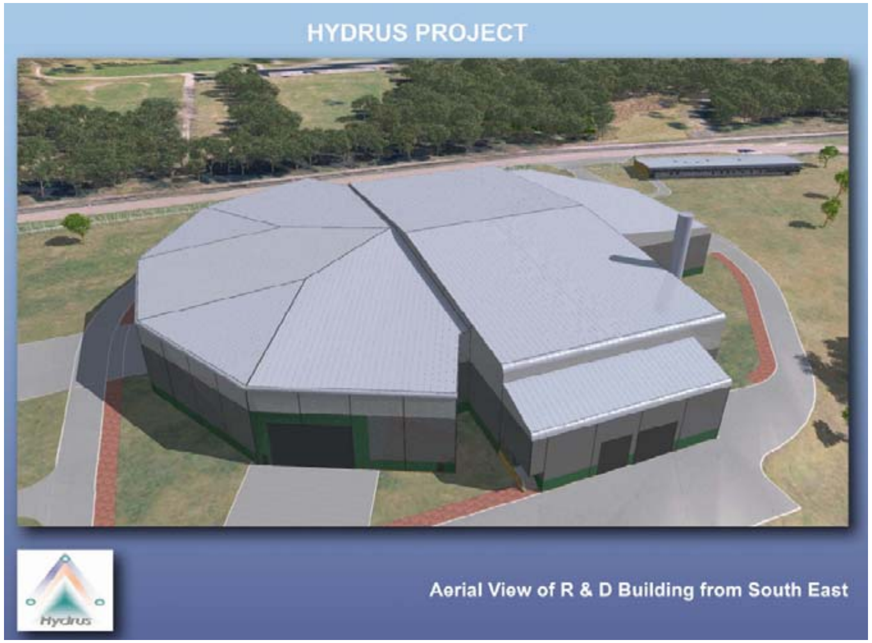
- **A new firing chamber coupled to multiple x-ray views**
  - **250R, 2.75mm spot progressing to 1000R from a 2mm spot**
  - **X-Ray peak energies from 7 to 14MeV**
  - **Machine firing jitter < 10ns**

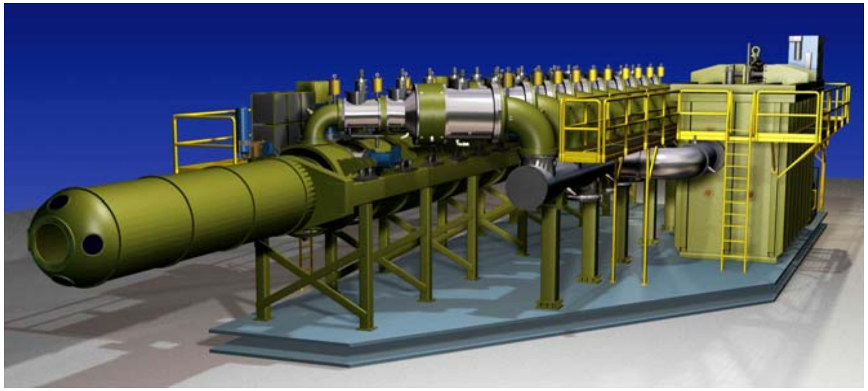
- **When fully realised this capability will surpass equivalent facilities elsewhere**

Project Hydrus

- **New purpose built firing chamber designed to handle higher charge weights than existing facilities**
- **Three radiographic axes with enhanced x-ray performance**

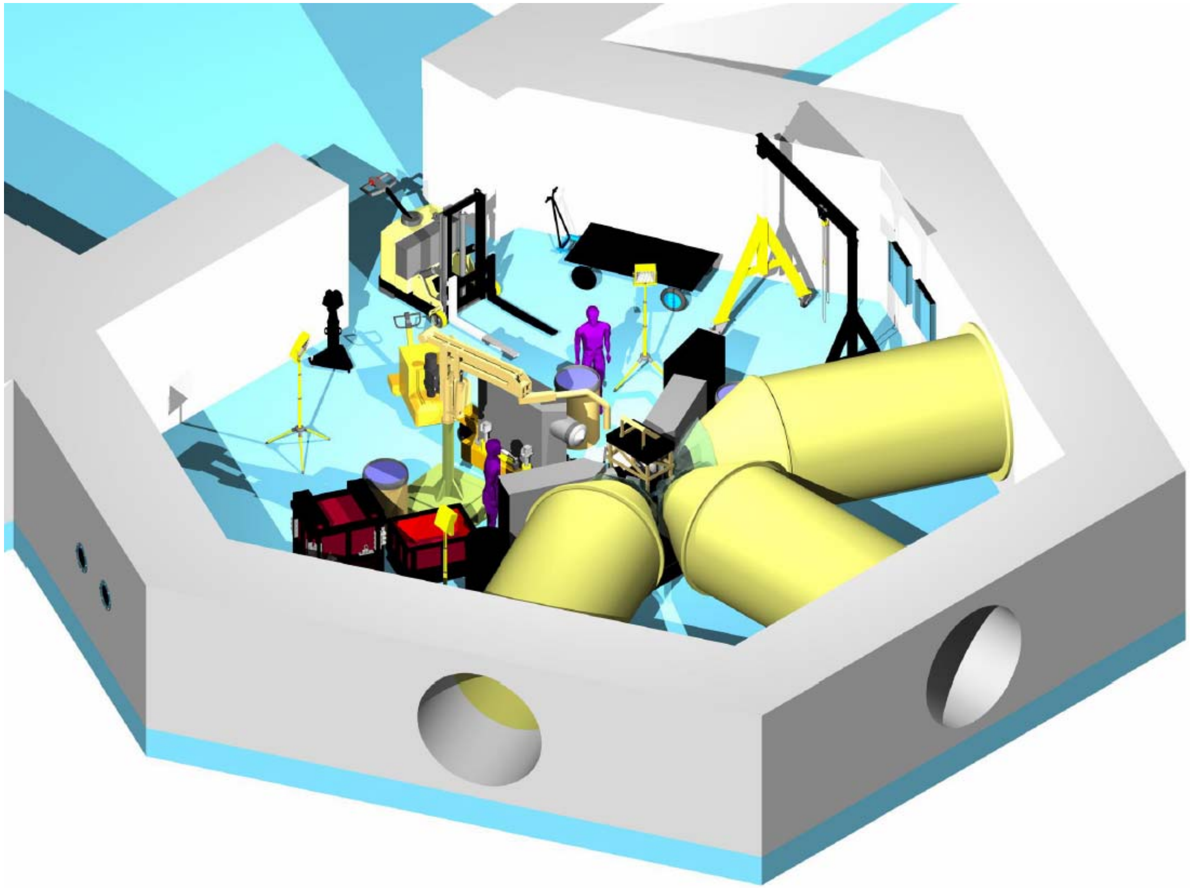






Project Hydrus

- **Firing Chamber - 3 views at 65 degrees**



Project Hydrus

- **Facility delivery will be phased to match the AWE experimental trials programme requirements**

- **A single view capability will be completed by 2015 using IVA technology**

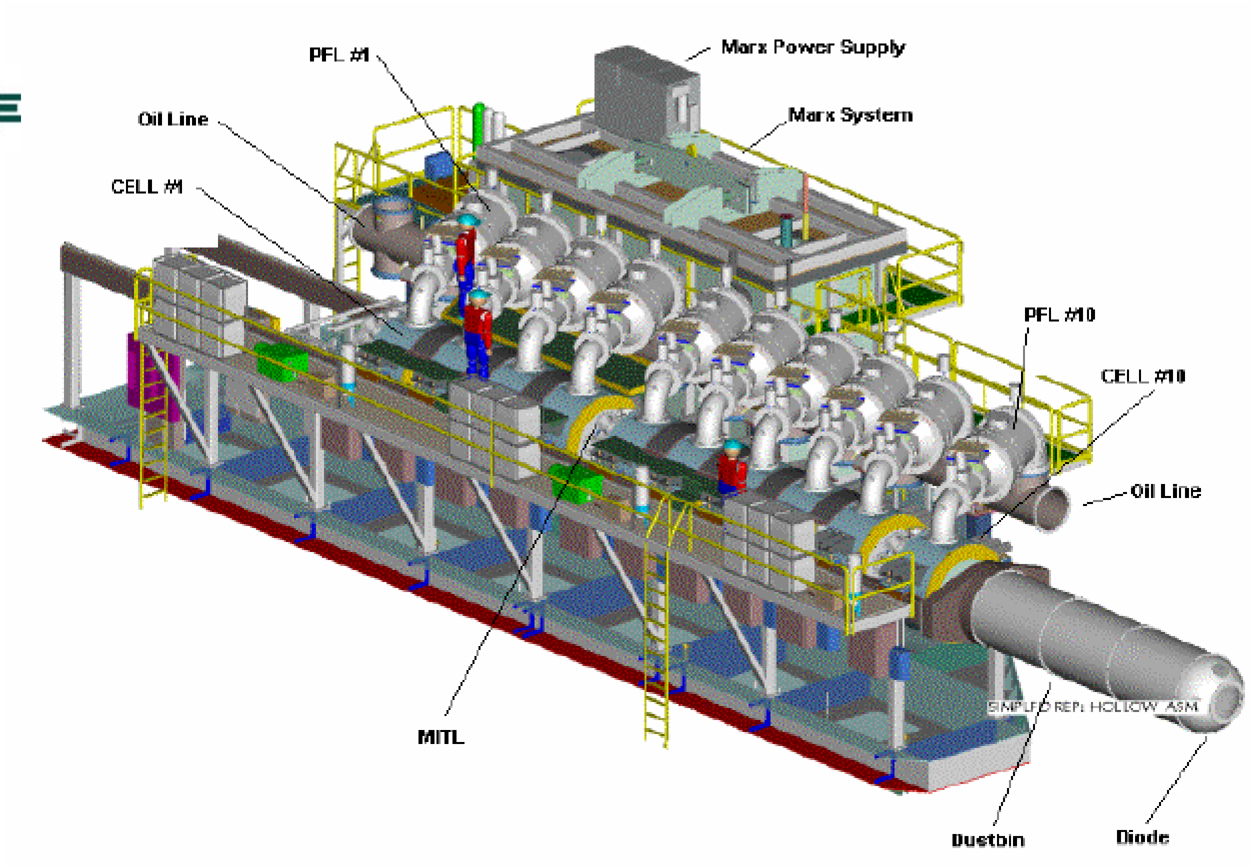
- **The second two views will be installed in a second phase, the Pulsed Power technology to be chosen at a later date**

- **Hydrus will form the enduring core of the experimental capability of the Hydrodynamics Department at AWE**

Flash X-Ray Source - IVA Machine

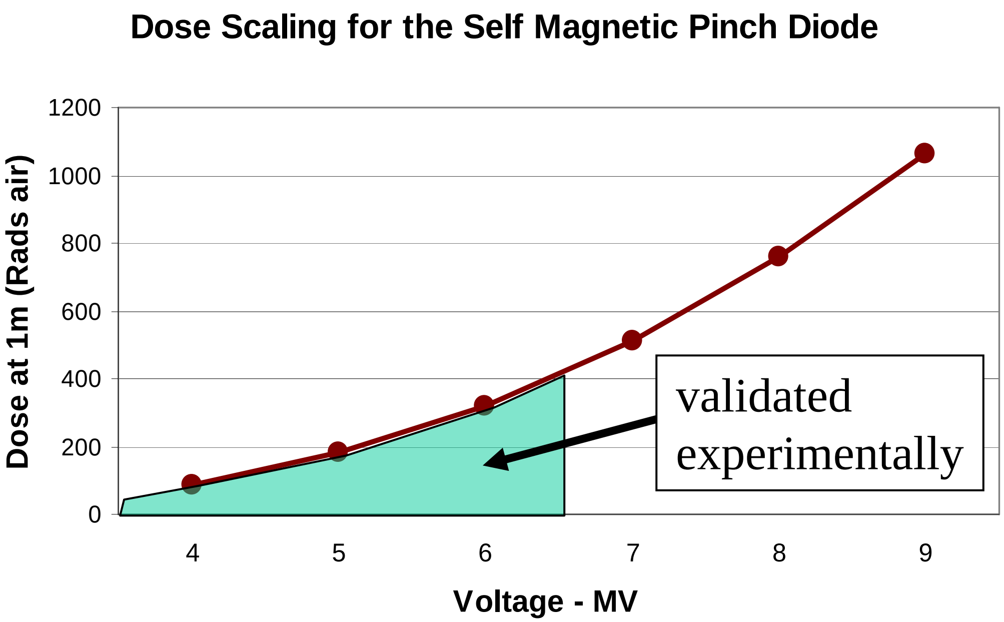
- **Inductive Voltage Adder (IVA) technology chosen for first x-ray machine**
  - **Very scalable and already demonstrated to 20MV on Hermes III**
  - **Mogul technology not proven above 10MV**

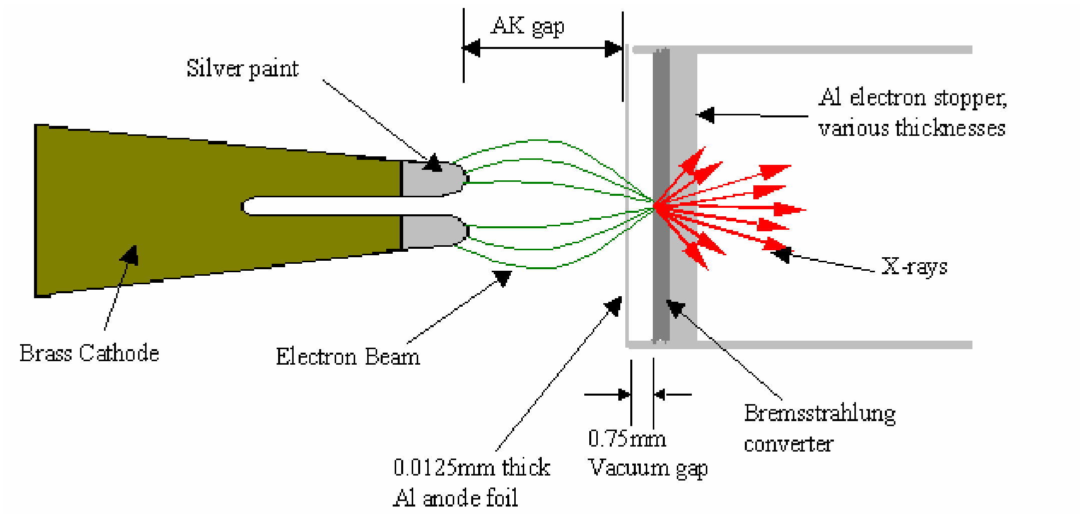
communications
Applied Technologies
Pulse Sciences



Flash X-Ray Source - Self Magnetic Pinch Diode

- SMP chosen as initial diode
- Already demonstrated on RITS-6 to exceed the initial x-ray performance goals
- Diode dose scaling so far has followed predictions



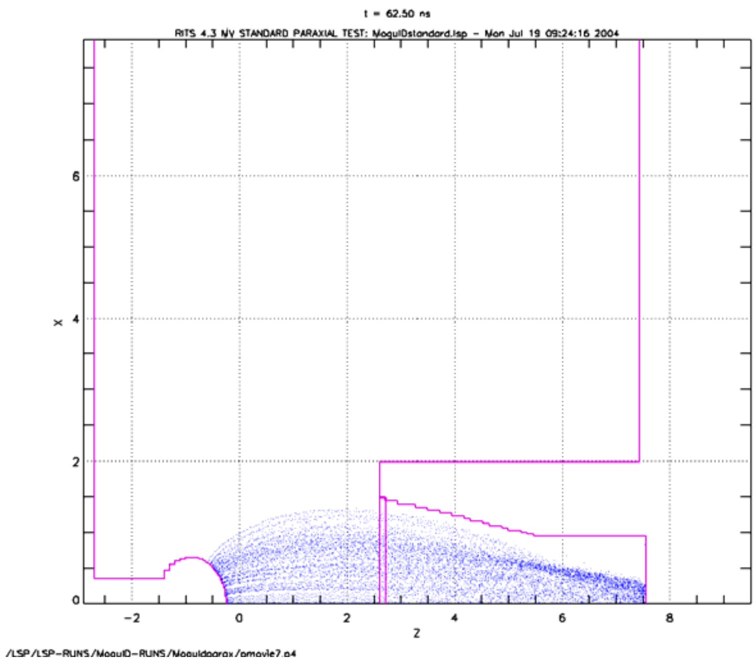


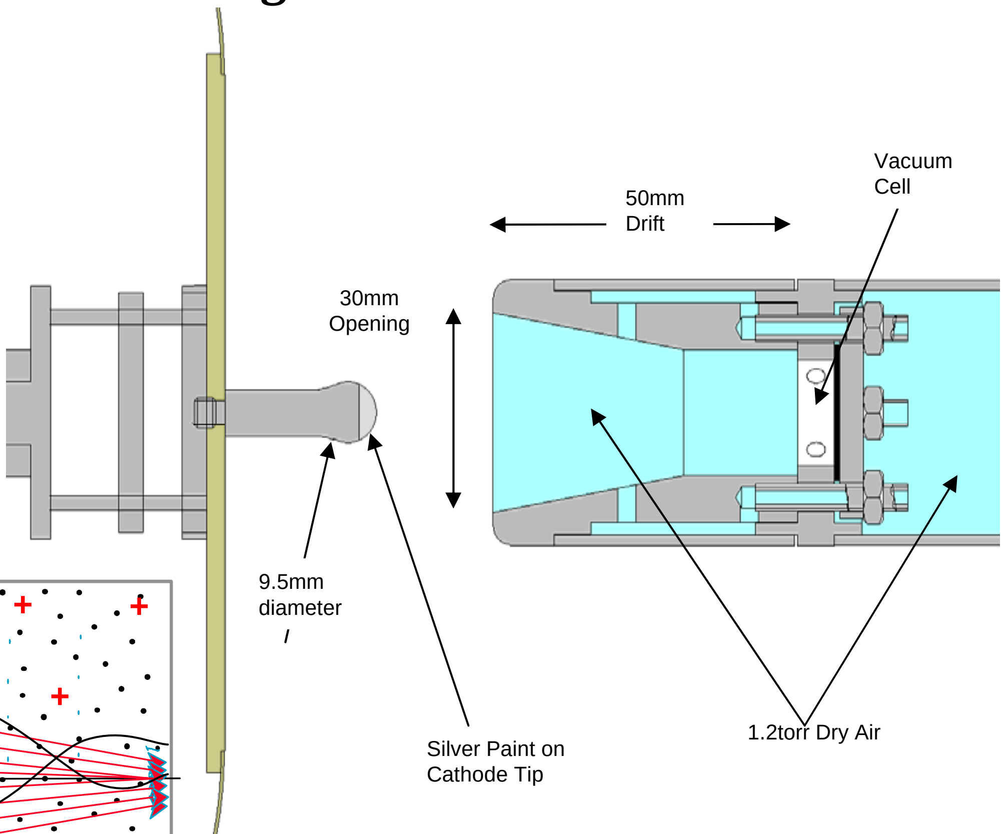
Continued Diode Research

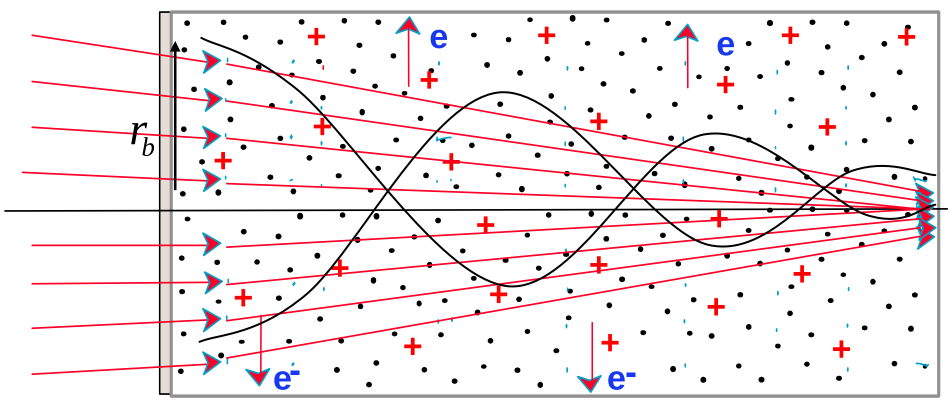
- **The SMP diode may not be able to reach the long term radiographic goals of Hydrus without significant modification to the IVA machine**
  - **The SMP diode works at a lower impedance than the IVAs were designed for, which lowers the peak voltage at the diode and reduces the ultimate dose achievable**
- **Higher impedance diodes need to be developed alongside the SMP to ensure the best solution can be found**
- **Current experience has shown that the higher impedance diodes have larger spots than the SMP making a more detailed understanding of their operation essential**
- **AWE also needs more intense sources at the sub 2MV range for radiography of 'thinner' objects to greater fidelity**

Paraxial Diode

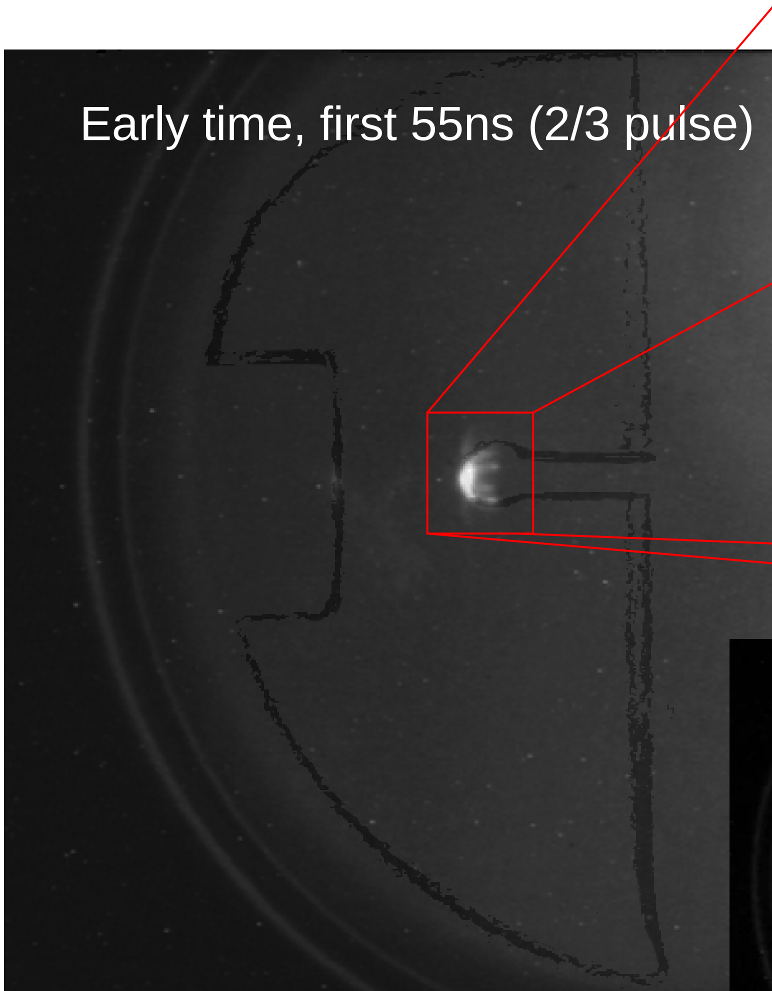
- **Current x-ray diode on Superswarf and Moguls**

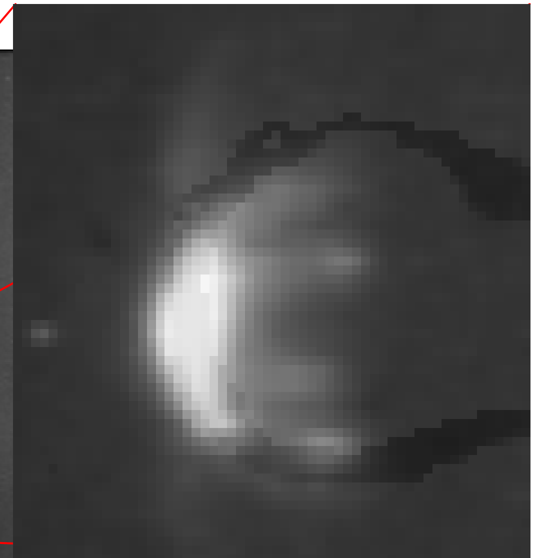


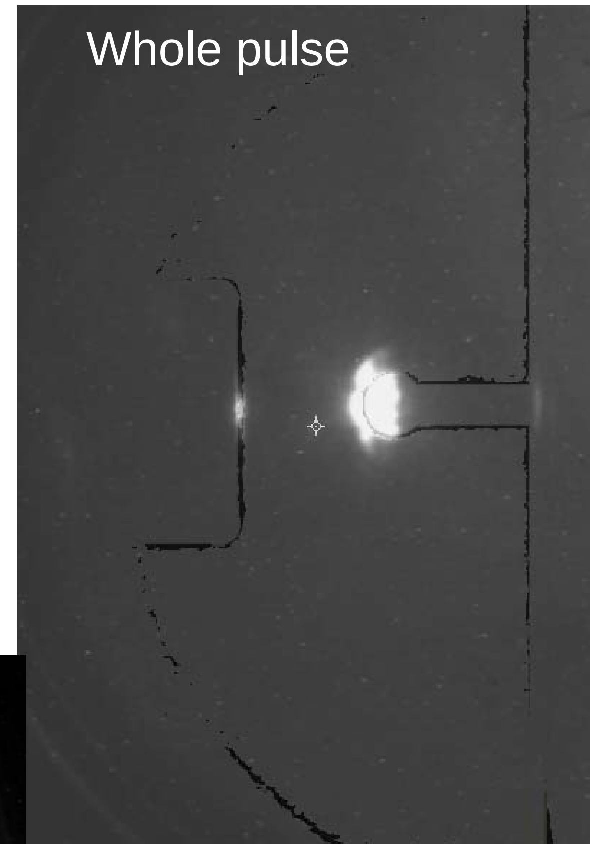


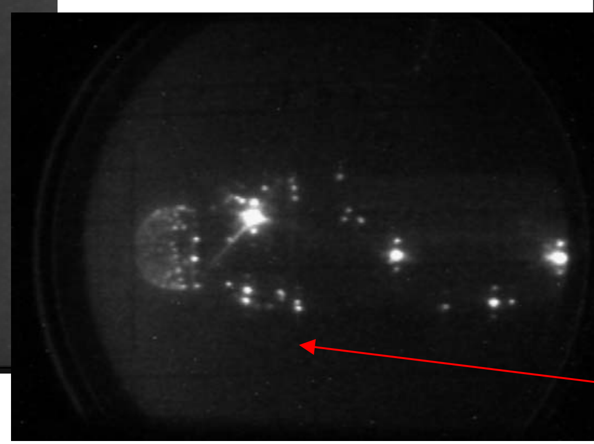


Optical Imaging of the Paraxial Diode





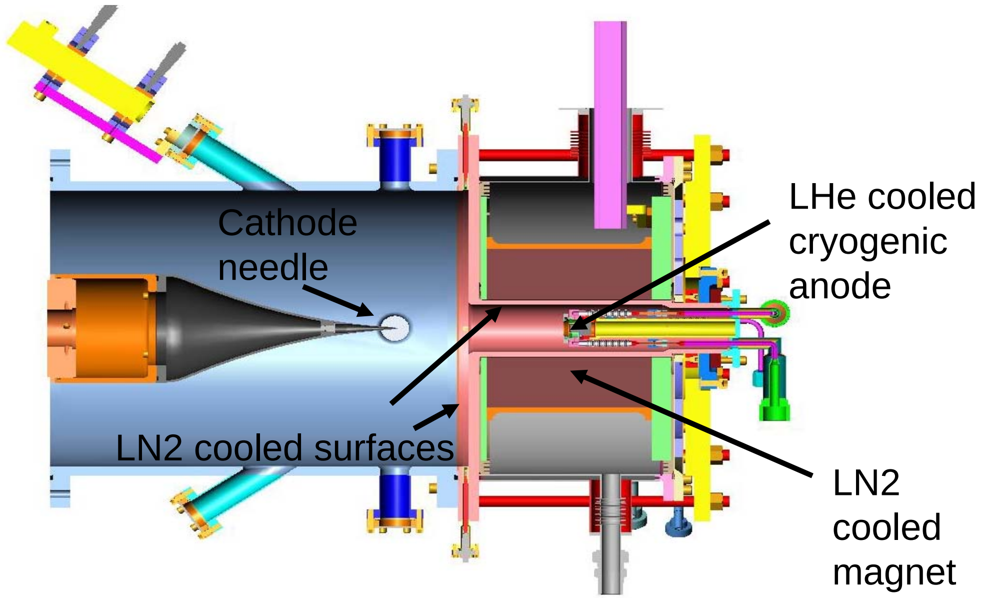


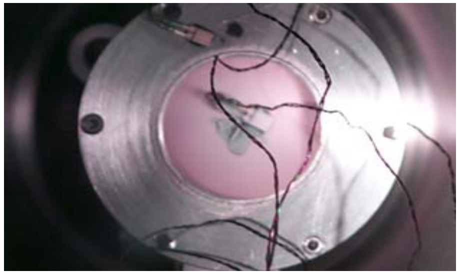


Large Area Cathode, whole pulse

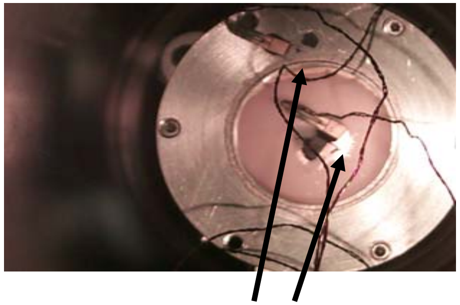
BZ Diode

- At one time this was the most promising diode
- Modelling progressed to an advanced state, predicting that having only protons present would improve performance
- Experiments failed to reach expectations and new thinking is required to further develop this diode



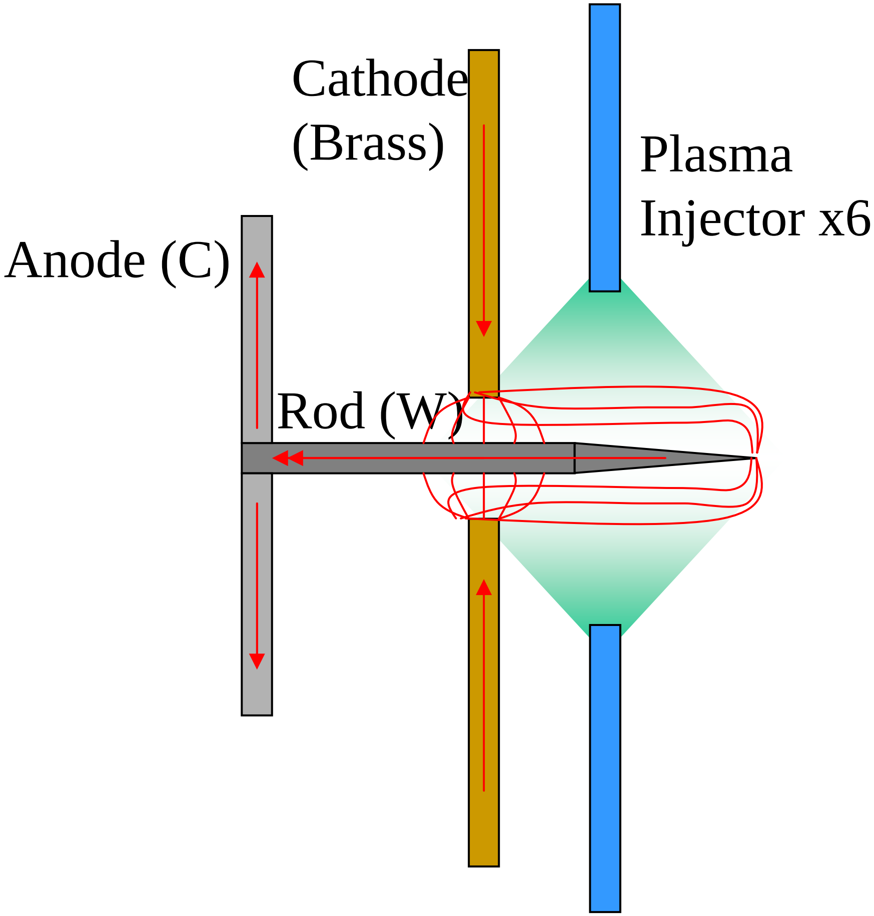


Anode coated with N2 ice after 10 minutes of coating

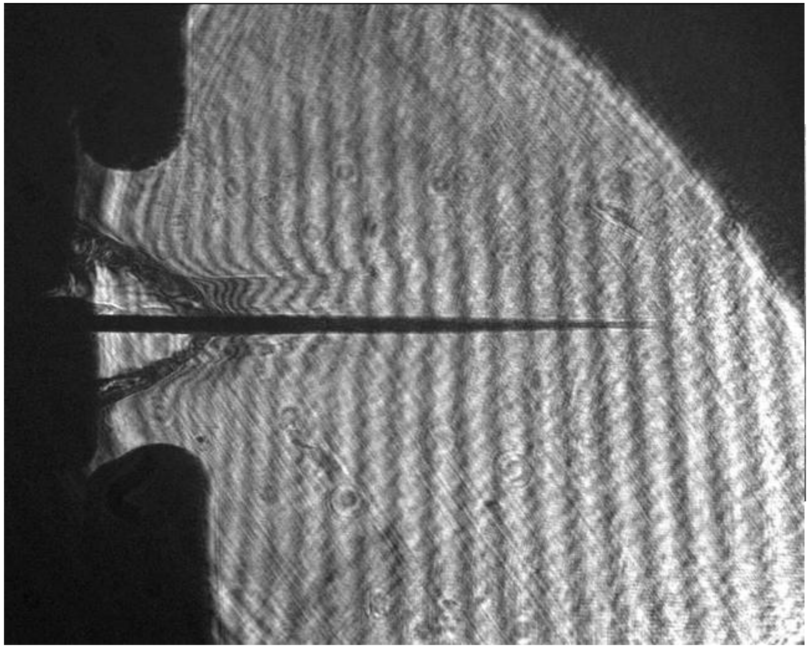


Once N2 ice started to melt you can see patches of shiny anode surface

Plasma Filled Rod Pinch Diode (PFRP)



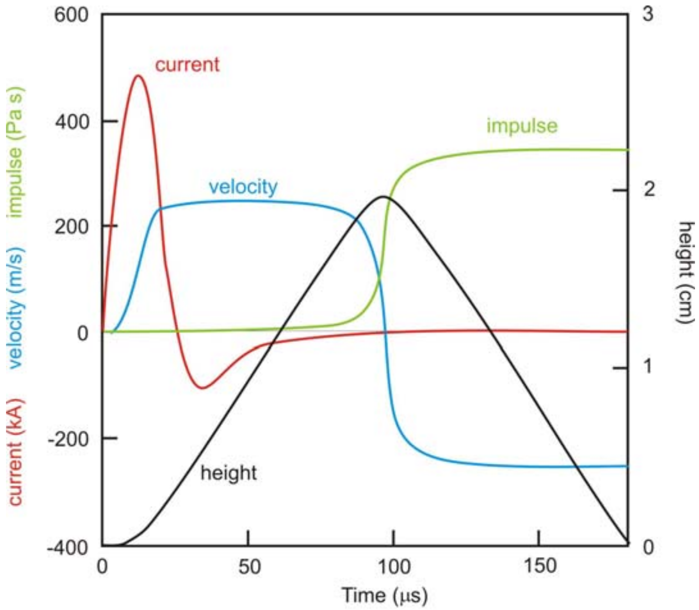
- Plasma fill the AK gap
- Initially acts as a near short
- J x B forces push the plasma towards the end of the rod
- Accelerating gap erodes near tip
- X-rays produced at tip



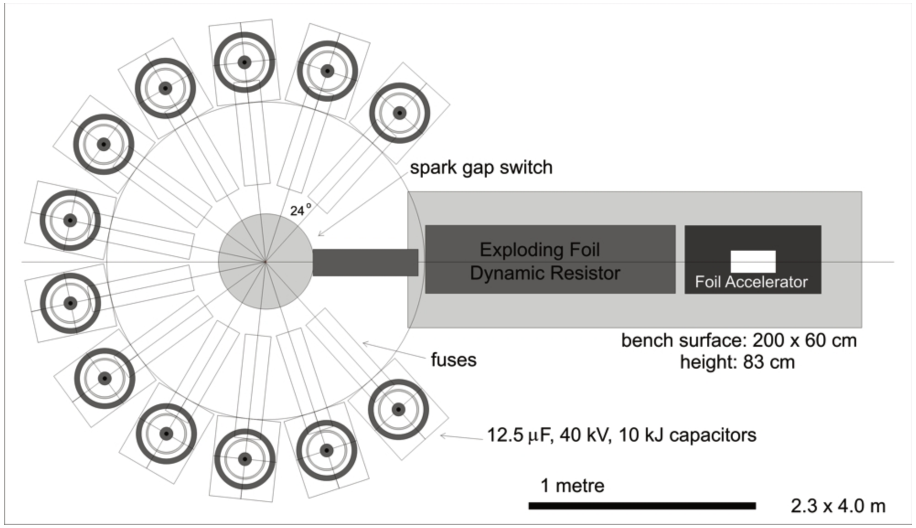
Other Pulsed Power Requirements and Research

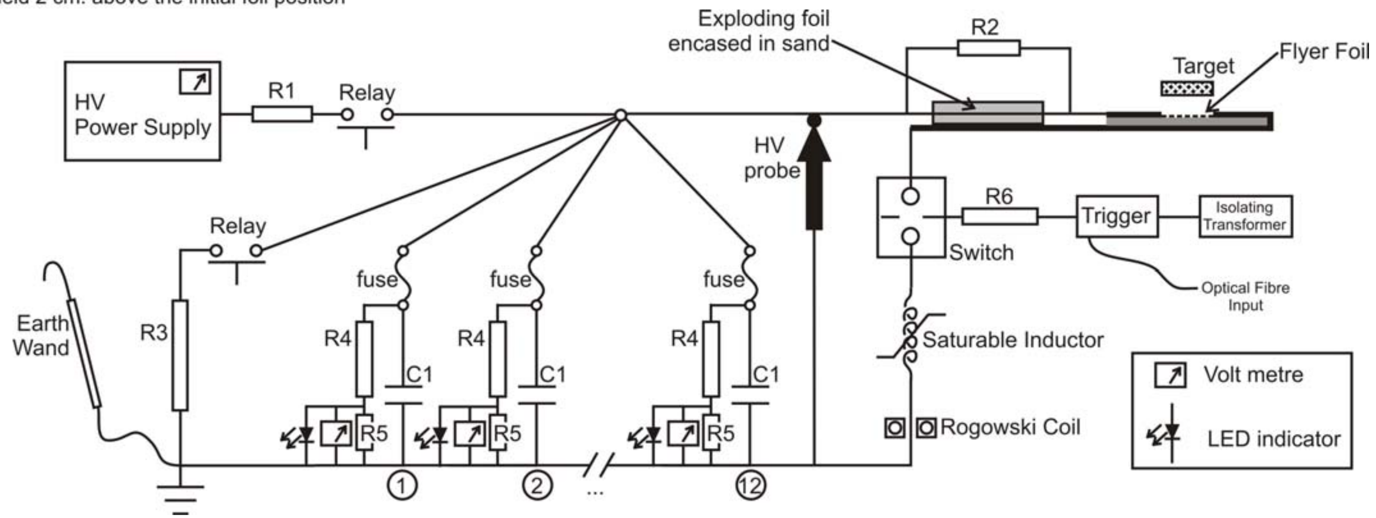
- **Future X-Ray sources are not the only demands on pulsed power at AWE**
- **The current x-ray machines need to have their reliability improved and their life extended**
  - **The Mini Bs are nearly 40 years old**
  - **Some of the machines will need new Marx generators**
- **Intense electron beam sources are needed for effects testing**
  - **Uniformity and predictability of the beam can of particular importantance**
- **The new Orion Laser has an extensive pulsed power requirement for the flash lamps need to excite the laser glass**
- **AWE is also reviving its capability to use pulsed power to generate shocks in materials**

Initial Pulsed Power Hydrodriver Designs



Modelled parameters of a magnetically driven foil impacting a target held 2 cm. above the initial foil position





Basic Pulsed Power Research

- All this work is driving a need to improve our knowledge base
- We need to better understand and measure plasmas
  - Strong collaborative links with Sandia and NRL
  - Academic links to Imperial College
- A better understanding of breakdown mechanisms is needed to design more compact machines
  - Research programme with Strathclyde University
- New pulsed power components
  - Solid state devices
  - High gradient insulators
- New machine architectures
  - DWA, LTD, etc
  - Multiple pulse machine concepts

AWE Pulsed Power Strategy

- This increased demand for pulsed power at AWE has lead to a need to develop a strategy for Pulsed Power
- The Pulsed Power Group in the Hydrodynamics Department is gaining greater responsibilities for Pulsed Power across AWE
- Fundamental to meeting the new demands and responsibilities is to increase the size of the group
  - 4 new scientists recruited in the past year with more to come
  - Creation of a dedicated engineering team
- Improved links with academia
- Stronger ties with the US pulsed power community and with Sandia National Labs in particular
- Renewed emphasis on fundamental understanding of pulsed power issues to enable research for future solutions

Pulsed Power at AWE

- **Vision**
  - To be a well respected centre of excellence for Pulsed Power design, flexible and innovative at the cutting edge of Pulsed Power with a proven track record of delivering solutions to Nuclear Weapon Stewardship problems.

- **Mission**
  - Provide near term radiographic solutions whilst growing a comprehensive capability to apply Pulsed Power solutions to Nuclear Weapons problems. We will do this by nurturing an innovative, flexible, team approach delivering successful outcomes in a stimulating environment.

Summary

- CTBT demands enhanced facilities with an extended life at AWE to ensure certification of the current and potential future weapon systems

- Project Hydrus forms the centre piece of the Hydrodynamics Departments plans to meet those demands

- Pulsed Power is a significant part of those plans

- A strong and vibrant Pulsed Power Group at AWE is essential if we are to succeed
  - Increased staffing
  - Improved links to academia, industry and research laboratories

Any questions?