DOWNLOAD PDF PLASMA ELECTRON AND LASER BEAM TECHNOLOGY

Chapter 1 : Electron Bean vs Laser Beam Welding | Element

Keyhole formation is common to electron beam welding, laser welding, and plasma arc welding, all of which are important techniques for high-quality, high-precision welding.

STFC Lasers are powerful, versatile research tools that underpin many key scientific and technological advances of the last 50 years. From understanding the nature and behaviour of cancer cells to helping unlock the world-changing potential of fusion energy, they have endless applications and offer limitless value in driving forward the process of discovery and innovation. Our Central Laser Facility provides an unparalleled range of state-of-the-art laser technology. Encompassing compact lasers that can pinpoint individual particles and high-power installations that can recreate conditions found inside stars, this unique facility accelerates sub-atomic particles, probes chemical reactions and delves deep into the biochemical and biophysical processes that make life possible. Fusing deuterium and tritium ions together releases energy Credit: Our laser development programmes are working towards the next generation of even higher power lasers, and towards making them more widely used for applications in healthcare, energy and engineering. So understanding the physics underpinning them is fundamental to our wider understanding of the Universe and how it functions. Plasma physics impacts on many key areas of scientific interest, from astrophysics to future energy sources and even next generation accelerator technology. Our Vulcan and Astra Gemini lasers are routinely harnessed to produce a whole range of plasma types in the laboratory. This provides the perfect environment in which academic and industrial researchers can experiment, explore and explain, as they pursue new knowledge and innovative technologies. Plasmas generated using high power laser pulses can be used to study astrophysical objects such as nebulae Credit: Shutterstock Novel particle accelerators and X-ray sources Shooting a super-intense laser pulse into a plastic or metallic target produces a plasma. Scientists are keen to fully understand and control this novel mechanism for generating radiation beams. Not only is the source itself much smaller than a centimetre, making it very compact compared to conventional sources that are at least a metre in size. The pulses of radiation are also extremely short, lasting only a trillionth of a second, making them very useful tools to capture very fast physics processes. Our Vulcan and Gemini lasers are regularly utilised in experiments that aim to optimise laser-driven radiation sources for applications including ultra-fast dynamic imaging, phase contrast imaging, particle-based cancer therapy and security scanning. Laser fusion power Fusion involves fusing two particles together to form new ones. This process occurs naturally under the extreme plasma conditions at the centre of stars, but achieving it on Earth is trickier. Yet it holds the key to electricity generation in the truly long term. If realised, fusion energy could provide a clean, safe, economic energy source for over a million years. The fuels are deuterium from sea water and tritium produced from lithium , which are isotopes of hydrogen and abundant on Earth. At temperatures of million degrees, deuterons and tritons can collide and fuse to produce an alpha particle and a highly energetic neutron. The big question is: Inertial confinement fusion ICF is one option. The idea is to use lasers to heat the exterior of a deuterium-tritium shell. The resulting rocket effect leads to an implosion that creates a very dense deuterium-tritium mass. In principle, a hotspot will be created and ignite the fuel, causing it to burn up through fusion reactions before the fuel can expand out again, leading to net energy gain. Fast Ignition ICF is a variation where an implosion produces a very dense mass of deuterium-tritium fuel without a hotspot, which is generated separately by sending in a laser-generated relativistic electron beam. This could lead to big savings in the scale of lasers required to drive the implosion, resulting in cheaper ICF and higher gain factors. Our ultra-intense Vulcan laser is capable of generating relativistic electron beams. Laser plasmas generated at our Central Laser Facility exhibit properties that make them similar to astrophysical plasmas in supernova remnants, in the cores of stars and planets, and in the early stages of galaxy formation. By mimicking astro-plasmas, our Vulcan and Gemini [link to Gemini page] lasers have enabled us to study the opacity of our sun, the material at the centre of Jupiter, the origin of magnetic fields in the Universe and plasma jet formation and interstellar flows. Strengthening plasma research To support the theoretical side of plasma research, we work with members of the plasma research community from all over the world, providing theoretical and computational support via the Plasma Physics Group at our Central Laser Facility [link to CLF page]. A key part of our activities involves working alongside international collaborations to interpret experimental data, as well as developing and providing access to world-leading plasma simulation codes. The Group is expertly equipped to address both fundamental and applied aspects of plasma physics research, including laser acceleration, laser fusion research and quantum effects e. In addition, high performance computing is needed to run plasma simulations codes fully and our dedicated computing clusters allow large simulations of this kind to be carried out. CALTA is developing a new generation of efficient, compact, transportable, adaptable high power laser and associated technologies. The main aim is to establish a robust technology platform on which direct applications of high power lasers can be commercially based. The first of these projects is DiPOLE, a laser system energised by an array of laser diodes that can fire high power pulses ten times per second. The aim is to enhance the power from 1 PW to over 20 PW and increase its focused intensity by over times, ensuring we retain our world-leading status in this field. Advancing laser physics In recent years, research at our Central Laser Facility has led to major advances in laser physics. The concept, which has been widely imitated and implemented worldwide, forms the basis of the proposed Vulcan 10 PW upgrade project. Our simulation codes have been used to demonstrate the feasibility of Raman amplification, a ground-breaking laser amplification method which takes long laser pulses and compresses them to times shorter but with intensities times greater. This means very complex, very expensive laser set-ups could eventually be replaced with smaller, more cost-effective systems â€” making many laser-based technologies far more accessible and easier to mass-produce. This development is another step in the quest to provide the ever more powerful lasers demanded by new technologies.

Chapter 2 : Plasma acceleration - Wikipedia

The design, operating principles, and characteristics of ultrahigh-density heat sources for welding and other materials-processing applications are discussed in 57 previously published papers written or cowritten by the author. Topics examined include electron, laser, and plasma beams; focusing.

Received Nov 20; Accepted Mar 6. This work is licensed under a Creative Commons Attribution 4. To view a copy of this license, visit http: Abstract Laser-plasma technology promises a drastic reduction of the size of high-energy electron accelerators. It could make free-electron lasers available to a broad scientific community and push further the limits of electron accelerators for high-energy physics. Furthermore, the unique femtosecond nature of the source makes it a promising tool for the study of ultrafast phenomena. However, applications are hindered by the lack of suitable lens to transport this kind of high-current electron beams mainly due to their divergence. Here we show that this issue can be solved by using a laser-plasma lens in which the field gradients are five order of magnitude larger than in conventional optics. We demonstrate a reduction of the divergence by nearly a factor of three, which should allow for an efficient coupling of the beam with a conventional beam transport line. Electron beams from laser-plasma accelerators 1 , 2 , 3 have typical normalized transverse emittances of about or below 1 mm mrad refs 4 , 5 , 6 , 7 , comparable or even smaller than those of linear accelerators delivering similar energies 8 , 9. Yet, this small emittance is mostly due to a sub-micrometer source size 10 , while the beams typically have rather large divergence of a few milliradians. Their energy spread, of a couple of per cents 11 , is also at least one order of magnitude larger than in linear accelerators. This raises several issues for the beam transport and hence for key applications of laser-plasma accelerators such as free-electron lasers and high-energy colliders 12 , 13 , 14 , In particular, the transverse emittance tends to increase during a free drift because electrons with different energies rotate with different velocities in the transverse phase space The emittance increase is tolerable 17 if the drift length. Regarding state of the art laser-plasma accelerators 5 , 7 , 11 , 18 , the above condition indicates that the drift length should be smaller than 1â€”5 cm, depending on the exact conditions. In other words, electrons must be focused within a few centimeters from the accelerator exit in order to be transported efficiently. Focusing the beam within such a short distance requires very high transverse field gradients. An electron beam transport line based on quadrupole technology will therefore degrade the quality of a laser-plasma electron beam, rendering it useless for most applications. As they can sustain much higher gradients, plasmas could help to drastically miniaturize focusing optics, similar to the miniaturization achieved by laser-plasma accelerators, and hence to avoid any emittance growth. Incidentally, the idea to use plasma to focus an electron beam 20 is almost as old as the idea to use plasma to accelerate electrons It was proposed to focus an electron beam using the radial fields created in the wake of the electron beam itself, when it propagates in a plasma. The so-called plasma lens was demonstrated in the context of conventional accelerators 22 , 23 , 24 , 25 , but it has not been considered for focusing electron beams from laser-plasma accelerators owing to the ultrashort length of these beams. Indeed, there is always a finite length at the bunch head over which the focusing is very non-uniform 26 , 27 ; for ultrashort bunches from laser-plasma accelerators this length is comparable to the bunch length The laser-plasma lens was recently proposed, and validated by three-dimensional particle-in-cell simulations, to solve this issue 29 , In the following, we present an experimental demonstration of this concept. First, we explain the principle of the laser-plasma lens. Then, we show that the strength of the lens can be optimized by tuning both the distance between the accelerator and the lens, and the electron density in the lens. Finally, we analyse the chromaticity of the lens and discuss the results. Results Principle of the laser-plasma lens In a laser-plasma accelerator, the wakefields in which electrons are accelerated present both longitudinal components, which are responsible for the energy gain 31 , and transverse components, which make electrons oscillate and lead to betatron radiation The idea of the laser-plasma lens is to use these transverse fields to focus the electron beam. Its principle is illustrated in Fig. A laser pulse drives a wakefield in a first gas jet, diffracts in free space, and drives again a wakefield in a second jet. As a result, an electron beam is generated and accelerated in the first jet, it then drifts in the free space, where the interaction with the plasma is negligible, and is focused by the transverse components of the wakefield in the second jet. In general, transverse oscillations in a laser wakefield cannot be used to focus an electron beam because the beam electrons oscillate out of phase there is no correlation between the electron position and its propagation angle. In a laser-plasma lens, the required synchronization is operated by the free drift. Because of this correlation, electrons oscillate almost in phase in the second laser wakefield the laser-plasma lens , except for a small detuning arising from the beam energy spread which impacts the oscillation frequency and from the dependance of r on r0. Thus, the plasma can act as a lens whose strength depends on its length and density. More specifically, the electron beam will be collimated if the focusing fields vanish when the transverse momentum is minimum for most electrons.

Chapter 3 : Laser, Particle Beam, and Plasma Technologies | Berkeley Nuclear Engineering

*Plasma Electron and Laser Beam Technology: Development and Use in Materials Processing [Yoshiaki Arata] on www.nxgvision.com *FREE* shipping on qualifying offers. x p hardback with black dustjacket, large tear to front of jacket, otherwise a very well preserved Technical Library copy.*

Received Dec 2; Accepted May 8. To view a copy of this license, visit http: Scaling these compact accelerators to multi-gigaelectronvolt energy would open the prospect of building X-ray free-electron lasers and linear colliders hundreds of times smaller than conventional facilities, but the 1 GeV barrier has so far proven insurmountable. Here, by applying new petawatt laser technology, we produce electron bunches with a spectrum prominently peaked at 2 GeV with only a few per cent energy spread and unprecedented sub-milliradian divergence. Petawatt pulses inject ambient plasma electrons into the laser-driven accelerator at much lower density than was previously possible, thereby overcoming the principal physical barriers to multi-gigaelectronvolt acceleration: Simulations indicate that with improvements in the laser-pulse focus quality, acceleration to nearly 10 GeV should be possible with the available pulse energy. However, their size and expense now threaten the future of teraelectronvolt-class accelerator research, exemplified by the recent discovery of a Higgs-like boson 2 , and inhibit wide availability of gigaelectronvolt GeV -class accelerators that underlie coherent X-ray sources used for biological, chemical and condensed matter research. In , Tajima and Dawson 3 proposed the idea of accelerating charged particles by surfing them on electron density waves propagating through underdense plasma in the wake of an intense ultrashort laser pulse. Two decades of experiments, enabled by wide availability of terawatt TW femtosecond fs lasers starting in the s, have yielded laser-plasma accelerators LPAs of millimetre-to-centimetre length 4 that capture and accelerate ambient plasma electrons quasi-monoenergetically to energy as high as 1 GeV 5 , with tails reaching 1. The quest for multi-GeV LPAs is motivated by the possibility of constructing compact linear colliders 9 for future high-energy physics research and table-top sources of ultrashort, coherent hard X-rays 10 for physical, chemical and biological studies of dynamics at the atomic scale. Both numerical modelling 8 , 11 and experimental diagnostics 12 have shown that bubble formation is essential for producing collimated, quasi-monoenergetic electron beams. Third, laser peak power P must be kept well above the critical power GW for relativistic self focusing. This enables the drive pulse to self focus and self compress during its initial non-linear interaction with the plasma, increasing its intensity to a level at which blowout occurs, and helps it to self guide over multiple Rayleigh lengths once acceleration begins, thereby exploiting the increased acceleration length set by LD and LPD. On the other hand, deviations from a matched geometryâ€”due to the focus geometry or non-Gaussian profile a likely feature of many first-generation PW-class laser systems of the incident laser pulseâ€”cause the laser pulse and bubble profiles to vary as they copropagate. Such variations profoundly affect self injection in ways not captured by simple scaling laws 13 , 14 , making self-injection thresholds difficult to predict accurately Moreover, details of bubble evolution dictate the dynamics of self injection, which in turn dictate key beam properties such as energy spread, angular divergence and background current 13 , 14 , In view of these uncertainties, previous work provides limited quantitative guidance on self-injection physics and beam properties of multi-GeV LPAs, which must therefore be discovered through laboratory experiments. Here we present the first experimental demonstration of self-injected, quasi-monoenergetic LPA of electrons well beyond 1 GeV energy. At the same time, our results show two features not predicted by any previous simulation or scaling law. First, self-injection and multi-GeV acceleration occur despite a highly irregular focal profile. These last features, along with the quasi-monoenergetic multi-GeV spectral peak, are critical for collider and coherent light source applications. Our results were obtained with an exceptionally simple target consisting of uniform, undoped He gas, similar to the target used by Osterhoff et al. Our results thus provide a benchmark against which future multi-GeV LPAs employing such methods can be compared. Results Generation and measurement of 2 GeV electrons Figure 1 shows a schematic layout of the experiments. Transversely scattered pump light was imaged through a side window in the cell. Accelerated electrons emerged through a 3-mm radius exit aperture and were deflected in a plane perpendicular to the laser polarization by a magnetic field from a permanent dipole magnet. The electron beam entered the field perpendicular to one edge, aimed nominally at the centre of the plateau. The measured field deflected electrons equivalently to a uniform, fringe-free effective field of 1. This effective field was used in calculating electron trajectories. Between magnet and detectors, electrons and X-rays passed through two arrays of thin, precisely positioned tungsten-wire fiducials, which cast identifying shadows on the detectors. With this information, complete electron trajectories from source to detector were recovered from shadows in the electron spectrum.

Chapter 4 : Electron beam or laser beam welding? - The Fabricator

The Group is expertly equipped to address both fundamental and applied aspects of plasma physics research, including laser acceleration, laser fusion research and quantum effects (e.g. particle production) expected to be observed with the next generation of ultra-high intensity lasers (e.g. the Vulcan 10 PW upgrade).

Under normal conditions the plasma will be macroscopically neutral or quasi-neutral , an equal mix of electrons and ions in equilibrium. However, if a strong enough external electric or electromagnetic field is applied, the plasma electrons, which are very light in comparison to the background ions by a factor of , will separate spatially from the massive ions creating a charge imbalance in the perturbed region. A particle injected into such a plasma would be accelerated by the charge separation field, but since the magnitude of this separation is generally similar to that of the external field, apparently nothing is gained in comparison to a conventional system that simply applies the field directly to the particle. But, the plasma medium acts as the most efficient transformer currently known of the transverse field of an electromagnetic wave into longitudinal fields of a plasma wave. In existing accelerator technology various appropriately designed materials are used to convert from transverse propagating extremely intense fields into longitudinal fields that the particles can get a kick from. This process is achieved using two approaches: But, the limitation of materials interacting with higher and higher fields is that they eventually get destroyed through ionization and breakdown. Here the plasma accelerator science provides the breakthrough to generate, sustain, and exploit the highest fields ever produced by science in the laboratory. What makes the system useful is the possibility of introducing waves of very high charge separation that propagate through the plasma similar to the traveling-wave concept in the conventional accelerator. The accelerator thereby phase-locks a particle bunch on a wave and this loaded space-charge wave accelerates them to higher velocities while retaining the bunch properties. Currently, plasma wakes are excited by appropriately shaped laser pulses or electron bunches. Plasma electrons are driven out and away from the center of wake by the ponderomotive force or the electrostatic fields from the exciting fields electron or laser. Plasma ions are too massive to move significantly and are assumed to be stationary at the time-scales of plasma electron response to the exciting fields. As the exciting fields pass through the plasma, the plasma electrons experience a massive attractive force back to the center of the wake by the positive plasma ions chamber, bubble or column that have remained positioned there, as they were originally in the unexcited plasma. This forms a full wake of an extremely high longitudinal accelerating and transverse focusing electric field. The positive charge from ions in the charge-separation region then creates a huge gradient between the back of the wake, where there are many electrons, and the middle of the wake, where there are mostly ions. Any electrons in between these two areas will be accelerated in self-injection mechanism. In the external bunch injection schemes the electrons are strategically injected to arrive at the evacuated region during maximum excursion or expulsion of the plasma electrons. A beam-driven wake can be created by sending a relativistic proton or electron bunch into an appropriate plasma or gas. This requires an electron bunch with relatively high charge and thus strong fields. The high fields of the electron bunch then push the plasma electrons out from the center, creating the wake. Similar to a beam-driven wake, a laser pulse can be used to excite the plasma wake. As the pulse travels through the plasma, the electric field of the light separates the electrons and nucleons in the same way that an external field would. If the fields are strong enough, all of the ionized plasma electrons can be removed from the center of the wake: Although the particles are not moving very quickly during this period, macroscopically it appears that a "bubble" of charge is moving through the plasma at close to the speed of light. The bubble is the region cleared of electrons that is thus positively charged, followed by the region where the electrons fall back into the center and is thus negatively charged. This leads to a small area of very strong potential gradient following the laser pulse. In this case, the linear plasma wave equation can be applied. However, the wake appears very similar to the blowout regime, and the physics of acceleration is the same. Wake created by an electron beam in a plasma It is this "wakefield" that is used for particle acceleration. A particle injected into the plasma near the high-density area will experience an acceleration toward or away from it, an acceleration that continues as the wakefield travels through the column, until the particle eventually reaches the speed of the wakefield. Even higher energies can be reached by injecting the particle to travel across the face of the wakefield, much like a surfer can travel at speeds much higher than the wave they surf on by traveling across it. Accelerators designed to take advantage of this technique have been referred to colloquially as "surfatrons". Comparison with RF acceleration[edit] The advantage of plasma acceleration is that its acceleration field can be much stronger than that of conventional radio-frequency RF accelerators. In RF accelerators, the field has an upper limit determined by the threshold for dielectric breakdown of the acceleration tube. This limits the amount of acceleration over any given area, requiring very long accelerators to reach high energies. In contrast, the maximum field in a plasma is defined by mechanical qualities and turbulence, but is generally several orders of magnitude stronger than with RF accelerators. Plasma acceleration is categorized into several types according to how the electron plasma wave is formed: The electron plasma wave is formed by an electron or proton bunch. A laser pulse is introduced to form an electron plasma wave. The electron plasma wave arises based on different frequency generation of two laser pulses. The "Surfatron" is an improvement on this technique. The formation of an electron plasma wave is achieved by a laser pulse modulated by stimulated Raman forward scattering instability. The first experimental demonstration of wakefield acceleration, which was performed with PWFA, was reported by a research group at Argonne National Laboratory in

Chapter 5 : Lasers and Plasma Physics - Science and Technology Facilities Council

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Both laser welding and electron beam welding produce extremely high quality joints. Which to choose depends, as always, on the job at hand. A laser beam welds a circumferential seam on a rotating workpiece. In some cases, the question has a simple answer, but often not, and the decision to use process A or process B comes down to a comparison of pros and cons, with cost as the thumb on the scale that tips the balance. For precision welding requirements, the choice is usually between electron beam welding and laser beam welding. Electron beams and lasers can be focused and aimed with the exceptional accuracy required to weld the smallest of implantable medical devices, and yet also deliver the tremendous amounts of power required to weld large spacecraft parts. Electron beam and laser welding are versatile, powerful, automatable processes. Both can create beautiful welds from a metallurgic and an aesthetic perspective. Both can be cost-effective. But for all the similarities, electron beam and laser welding are wildly different from each other in terms of underlying physics and functional operation in the real world of the shop floor. It is in these differences that one particular process might have an edge for a particular application. Key to finding the particular characteristics that might make one more suitable than the other is understanding how electron beam welding and laser welding work. On the surface the two seem the same, but the devil is in the details. Electron Beam Welding Electron beam welding was developed in the late s. It was quickly embraced by high-tech industries, such as aerospace, for the precision and strength of its resultant welds. An electron beam can be very accurately placed, and the weld can retain up to 97 percent of the original strength of the material. It is not an exaggeration to state that EB welding, in terms of the quality of the weld, is unbeatable: EB welding is simple to explain. A tungsten filament is heated and power is applied to the point that the filament gives off electrons. When these electrons strike a metal part, the kinetic energy is transferred to the molecular lattice of the material, heating it almost instantaneously. In fact, an electron beam welding system can throw enough power to simply vaporize metal a process called electron beam machining. EB welding machines generally come in two power classifications, low voltage 60 kV or high voltage kV. A typical high-voltage machine rated to 7, watts can produce a weld in steel 2 in. A vacuum requires a vacuum chamber, so the size of a part to be welded is limited by the size of the chamber. Vacuum chambers can be small or large, but the larger the chamber, the longer it will take to establish the proper vacuum level, which is at a minimum 1. The use of a vacuum, as well as the presence of X-radiation a byproduct of the beam , precludes human handling, so the entire process has to be externally controlled, generally using CNC tables. EB welding has been fully automated for decades. The collusion of all this technologyâ€"high voltage, vacuum, and high-tech automationâ€"means that EB welding requires well-trained operators and very competent maintenance, and that the setup and running of an EB welding system can be expensive. EB welding is a fusion welding process and thus requires a precise fit between the parts being welded, as a filler material is generally not used or required. The parts must also be securely fixtured to a motion-controlled table to precisely move the areas to be welded into contact with the electron beam. Secure fixturing also minimizes the effects of shrinkage and warping during welding. The electron beam has to be carefully calibrated and focused and timed with the CNC motion to deliver a consistent weld with uniform penetration and minimal porosity. Each welding cycle involves loading the welding chamber, pumping down the vacuum, welding the part, and then venting the vacuum. Electron beam welding can produce extremely high-quality welds, but the process must be performed in a vacuum. Hence, it is imperative that the engineers and technicians involved maximize the number of parts to be welded each cycle and optimize the movement of the CNC table. When this is all done correctly, electron beam welding can achieve very high quality and high cost-effectiveness. Electron beam welding systems can weld all weldable metals and some metals that are not typically welded. EB welds are incredibly strong and pure. Impurities in the weld are vaporized, and welding in a vacuum means there are no gases or air to react and cause oxides. EB welding can also join dissimilar materials that would otherwise be unweldable due to differences in melting points, which result in intermetallic compounds that cause brittleness. The precise nature of the electron beam and tight heat-affected area allow EB welding to basically melt the lower-temperature material onto the unmelted, higher-temperature material, resulting in a compact, vacuum-tight weld. It can be a bit cumbersome to deal with, but the products of EB welding are first-class in all respects. Laser Beam Welding Lasers were developed in the early s, and by the mids CO2 lasers were being used to weld. A decade later automated lasers were welding on production lines, and the technology has continued to improve and find wide acceptance in many industries. A laser welding system is capable of delivering a tremendous amount of energy very quickly and with pinpoint accuracy. The beam can be focused and reflected to target hard-to-access welds, and it can be sent down a fiber-optic cable to provide even more control and versatility. Lasers basically work by rapidly raising and lowering the energy state of a material, which causes the emission of photons. How this occurs depends on the type of laser, be it a CO2 or solid-state system like Nd: YAG or fiber laser. When the photons are focused on the surface of a part, radiant heat melts the material in the heat-affected area and travels down through the part via conduction. This means of applying heat is very different than that of EB welding. The power output of a laser can vary from a few watts to hundreds of kilowatts, and different types of lasers have different welding characteristics. Laser welding generally requires the use of a cover gas to keep oxygen out of the weld area and improve efficiency and weld purity. The type of gas used depends on the type of laser, the material being welded, and the particular application. Some laser welding applications, such as hermetic sealing, require the use of a sealed glove box to provide a completely controlled environment. Over the past few years work has been done with laser welding in a vacuum. This method has yielded interesting results but has not yet been widely accepted in the industry. One challenge with laser welding involves reflectivity. This can minimize penetration and damage material in the vicinity of the weld joint. Pulsing in general is a useful method of laser welding because the amount of heat applied to the part is minimized, which limits part deformation. The alternative to pulsing is continuous wave CW. As the name implies, CW lasers utilize a laser beam that is on continuously. CW lasers are useful for cutting applications or when weld speed is important. Laser beam welding can achieve good penetration, typically up to about 0. Laser welding can usually join crack-prone materials, such as certain types of steel and aluminum, and much like EB welding, lasers can join dissimilar materials. Lasers are adept at applying the minimal amount of heat to a part, which makes them a good choice for welding electronics packages, particularly those that are hermetically sealed. Minimal heat means the weld can occur extremely close to sensitive electronic components and solder joints without damaging them. Lasers are also popular for medical device applications as the welds can be quite small with minimal discoloration of the part, and often the weld can be applied without the need for any secondary machining. So Which Process to Use? Which process is best usually depends on the particularities of the application. Laser welding is usually the process we look to first for a new application. Without the requirement for vacuum, laser welding is generally less expensive than EB welding, and the parts are easier to tool and fixture. If deep penetration is required, EB welding is the process of choice. Deeper penetration can also make a difference when it comes to materials with high thermal conductivity, such as copper. A typical laser welding system can penetrate only about 0. Dissimilar metal combinations generally weld better with EB, but there are some applications in which lasers work better. Hence, the weld quality requirements might make an impact on the choice of process. EB welding grew out of the aerospace industry before lasers were available. As a result, the specifications for EB welding are complete and widely accepted. These specifications control all aspects of the process, including joint design, cleaning, vacuum requirements, machine qualification, operator training, and inspection criteria. Laser welding is not as tightly controlled. This puts more onus on the engineer to understand all aspects of the process in order to make sure it is performed correctly. Frankly, it is difficult and somewhat disingenuous to list typical electron beam weld applications, or typical laser beam weld applications, because each use case is unique. Laser welding can work well for small parts, but the dynamics of part heat sensitivity might make electron beam the better option. Often one or two critical factors make the process choice very simple. All things being equal, laser welding is generally more cost-effective, while electron beam makes the absolute best weld joint. EB welding can achieve high production speeds with the right part and the right fixturing, and laser beams can make beautiful, pure welds with the right materials and setup. Electron beam and laser welding are excellent means to fuse metals. Both processes are flexible, versatile, and when properly applied can make strong welds. The choice of which to use lies at the intersection of the weld requirements and the particularities of each process. You May Also Like.

Chapter 6 : High-energy beam welding technology (2)

The previous chapter was concerned with laser and particle beams insofar as they are used to produce HED plasmas, whereas this chapter is concerned with the physics of the beam-plasma interaction itself.

It is perhaps not surprising, then, that the interaction of these powerful beams with plasmas yields a host of new, and often very similar, physical phenomena. For example, both types of drivers may ionize material or create new matter through pair production. They may cause plasma blowout, produce nonlinear plasma wakes, self-focus, filament, scatter, hose or kink, form braided beamlets, generate radiation, accelerate particles to ultrarelativistic energies, and even refract at a boundary in a similar way see Figure 4. These physical phenomena make up the intellectual theme of this chapter. The questions they raise make up a rich subfield for basic physics research. Answering these questions is of importance for a variety of applications for science and society. The answers may, for example, lead to breakthrough progress toward fusion energy, compact high-energy particle accelerators, and novel imaging techniques. They may also help us to understand the mechanism of ultra-high-energy cosmic ray UHECR acceleration and the formation of cosmic jets. The next two sections outline the fundamental physics questions and phenomena associated with high energy density beams in plasmas. Laser-Plasma and Beam-Plasma Interactions. Frontiers in High Energy Density Physics: The X-Games of Contemporary Science. The National Academies Press. Katsouleas, University of Southern California. Then, in the secion on applications of HED beam-plasma physics, three applications are described rather extensively, followed by coverage of seven other applications. At what intensities does dense matter become transparent? At what intensities does vacuum become opaque? Page Share Cite Suggested Citation: Can macroscopic amounts of relativistic matter be created in the laboratory and made to exhibit fundamentally new collective behavior? Can we predict the nonlinear optics of unstable, multiple-interacting beamlets of intense light or matter as they filament, braid, and scatter? Can the ultrahigh electric fields produced by laser wakes be used to make a tabletop accelerator with the luminosity and beam quality needed for applications in high energy and nuclear physics? Can lasers and particle beams simulate relativistic shocks and gamma-ray bursts in astrophysics? Are the same mechanisms responsible for laboratory plasma accelerators and plasma lenses also operating in the acceleration of particles from supernovae and the collimation of cosmic jets? Can ion beams produced by relativistic laser-plasma interactions be used as a source for beam-plasma physics, a diagnostic probe, or as a front-end component for accelerators? Can such interactions produce novel or economic radioactive ion sources? In reality, beam propagation is more complexâ€"beams filament, Raman scatter, frequency shift, and so onâ€"even in ordinary media. When the beams reach the high energy densities that are the subject of this report, the medium through which they propagate becomes necessarily a plasma. The nonlinear optics of extreme beams, with their associated gigabar pressures, teravolts per centimeter electric fields, and gigagauss magnetic fields, is no less rich than in regular media. The beams exhibit a wide range of propagation phenomena. These include the familiar, such as focusing and stimulated scattering instabilities, as well as the less familiar, such as braided light and relativistic shocks. In addition, the beam-plasma interactions lead to new radiation-generation mechanisms and to the high-gradient acceleration of particles in the plasma. Recent advances in experimental and computational capabilities are creating exciting new opportunities on two fronts: In the first category are questions such as: Can we predict the evolution of one or several beamlets propagating through a dense plasma? The importance of this question for laser fusion has been appreciated for more than 30 years. Many advances have been made, yet the answer remains an open challenge. It requires detailed understanding of parametric processes such as Raman and Brillouin scattering in the presence of trapped particles and complex thermal transport. At the other end of the spectrum are new questions and opportunities that arise as a result of the tremendous advances in short-pulse laser and particle beam technology. One of these is the fast ignitor: Can a short laser pulse be used to accelerate and deliver hundreds of mega-amperes of plasma electrons in a short burst to the core of a fusion fuel pellet and ignite it? The answer to this question may contribute to realizing the international goal of fusion ignition. Other questions emerge at still higher laser and beam energy densities. Chirped pulse amplification

CPA laser technology has enabled a proliferation of multiterawatt laser systems. When focused, their peak fields exceed several gigavolts per centimeter, and the quiver energy of electrons in these fields exceeds several MeV. These HED beams are creating macroscopic amounts of relativistic matter in the laboratory for the first time. Not surprisingly, they are producing a bounty of new relativistic phenomena such as relativistic transparency. At this point, the plasma becomes transparent to the laser pulse it would normally reflect. Other examples of relativistic phenomena accessible with current laser technology include highly nonlinear plasma wakes in which the plasma is driven to complete blowout, ultrastrong plasma lensing of both photons and particles, and intense radiation generation from the terahertz to x-ray frequency range by various mechanisms. Electron beams with energies up to MeV with small normalized emittance of order millimeters to milliradians and nanocoulombs of charge have been generated by plasma wakes in millimeter gas jets. Although the electron beams in these experiments had large energy spreads, the acceleration gradient they achieved was more than a thousand times the gradient of a conventional linear accelerator. This leads to the question: Can wakefield acceleration yield sufficient energies and beam quality so as to enable high-energy physics on a tabletop? Can short plasma lenses enhance the final focus of a linear collider? On the horizon are yet higher density beams and lasers. Chirped pulse amplification technology applied to high-energy lasers is making it possible to consider multipetawatt- to exawatt-class lasers in the near future. The focused field gradients of such lasers will exceed teraelectronvolts per centimeter, and the quiver energies will exceed gigaelectronvolts. As such extreme beams propagate in plasma, they can be expected to create copious electron-positron pairs and possibly heavier pairs. It may be interesting to consider questions such as: Can beams undergo a stimulated pair scattering instability by coupling parametrically to the pairs they create? Can backscatter amplification or other techniques be used to make even higher energy density pulses, exceeding even chirped pulse amplification limits? Using ultrahigh-intensity lasers, it may become possible to simulate some of the properties of black holes. This high acceleration could be used to study Unruh radiation, which is similar in many respects to Hawking radiation, induced by gravitational fields. But it is interesting to study at very large accelerations whether, as Unruh has suggested, there is radiation beyond that predicted by Maxwell. At sufficiently high intensities, even vacuum can be broken down. Although such fields are beyond the horizon, other nonlinear quantum electrodynamics effects could be accessed at more modest fields. For petawatt, kilojoule-class lasers, a nontrivial pair probability density can be created. It may be possible to scatter off of this grating with a third laser, thereby demonstrating the nonlinear optics of vacuum. Finally, it is noted that an alternate path to the Schwinger field could be an x-ray free-electron laser. Three Important Applications Multi-GeV Electron Acceleration in Plasma Wakefields The high cost and size associated with conventional rf accelerator technologies has been a prime motivation in advanced accelerator research for more than two decades. Wakefield accelerators driven by high energy density laser or particle beams promise an entirely new type of technology for building compact high-energy accelerators. Laser pulses propagating in plasmas can generate large-amplitude plasma waves, that is, wakefields, which can be used to trap and accelerate electrons to high energies. The amplitude of the plasma wave is largest when the laser pulse duration or its modulation is on the order of the plasma period. This laser-plasma interaction forms the basis for the laser wakefield accelerator LWFA. A wealth of new and interesting experimental results on LWFAs has been obtained in recent experiments around the world see Figure 4. On the theoretical and computational front, detailed analyses of the propagation and stability properties of intense laser pulses in plasma channels have been conducted. Recent advances in algorithms and high-performance computing are enabling fully self-consistent modeling of full-scale wakefield experiments in three dimensions for the first time. This work provides a strong foundation for next-generation wakefield accelerator research aimed at producing electron beams with gigaelectronvolt energies and high beam quality. To reach multigigaelectronvolt electron energies in an LWFA, it is necessary to propagate an intense laser pulse long distances many Rayleigh ranges in a plasma without disruption. However, a number of issues associated with long-distance propagation in plasma must be resolved before a viable, practical high-energy accelerator can be developed. These issues include optical guiding, instabilities, electron dephasing, and group velocity dispersion, all of which can limit the acceleration process. The scale length for laser diffraction is given by the Rayleigh range; therefore, the acceleration distance is limited to a few Rayleigh ranges. Since this is far below that necessary to reach gigaelectronvolt electron energies, optical guiding mechanisms such as relativistic focusing, ponderomotive channeling, and preformed plasma channels are necessary to increase the acceleration distance. There is, in fact, ample experimental confirmation showing extended guided propagation in plasmas and plasma channels. Another approach to achieving longer acceleration distances is being pursued at several particle beam facilities. These take advantage of the natural tendency of particle beams to propagate longer distances without spreading, compared to lasers. For example, at the SLAC, electron beams have been used to generate wakefields over a meter and to accelerate electrons by as much as MeV. Lasers incident on solid targets can also be used to accelerate heavier particlesâ€" protons and ions. The generation mechanism has been attributed to the electrostatic field set up by the escaping jet of hot electrons from the back of the target. Over the past four decades, the energy of these lasers has increased at a rate comparable to the growth in computer power, culminating in the National Ignition Facility NIF now under construction. The field of laser-plasma interactions is a vital enabling technology for these many applications as well as a remarkable testbed for understanding broadly applicable nonlinear plasma science. The challenges associated with the interactions of long-pulse high-energy lasers with plasmas is well illustrated by considering the nominal hohlraum target for achieving ignition on the NIF. As shown in Figure 4. The relative power in these cones is tuned to provide the time-dependent x-ray symmetry required for the implosion. Excellent absorption of the laser beams is desired, and excellent temporal and spatial control of the absorption is required for the requisite implosion symmetry. The interaction physics is extraordinarily rich. The beams can undergo enhanced bending in places where the plasma flow is near sonic, where significant energy transfer among crossing beams can also occur. The schematic on the right shows the hohlraum irradiated by NIF beams. Courtesy of Lawrence Livermore National Laboratory. Understanding and controlling their evolution in new regimes and over the centimeter scales and higher energies at NIF pose a significantly greater challenge.

Chapter 7 : Plasma Science and Technology - Applications - Technology

Electron beam welding (EBW) and Laser beam welding (LBW) are two very popular methods of joining multiple metallic components. But which process is the most effective? The answer to this question depends on the welding application.

February 1, , Lawrence Berkeley National Laboratory Schematic of the first experiment to achieve staging of laser plasma accelerators LPAs with independent laser pulses: The resulting electron beam is focused by a capillary-discharge plasma lens and then penetrates a moving tape. Almost simultaneously, an incoming pulse from laser 2 strikes the tape and creates a plasma mirror, which combines the laser beam and electron beam. Entering stage 2, a capillary-discharge LPA, the second laser pulse creates a wakefield in the plasma which further accelerates the electron beam; downstream diagnostics at right measure the beam. Past those few centimeters, however, the laser pulse weakens and energy gain stalls. LPAs will have to get off the tabletop if they are to rival proposed conventional colliders, such as kilometer-long electron-positron linear colliders or circular proton colliders kilometers in circumference, with electron-volt energies in the trillions TeVs , not billions. Only by coupling a hundred LPAs in series, each powered by a BELLA-class laser in series, and accelerating a well-shaped beam from one stage to the next, will such high energies be achieved. The results are reported in the Feb. The more advanced but more finicky type is a discharge capillary, a block of sapphire with a thin horizontal tube through it. Hydrogen gas fills the tube; a potent electrical discharge ionizes it, separating electrons from their nuclei and forming a plasma. Almost instantly this discharge arc heats the plasma and forms a laser waveguide, a cylindrical channel of thinner plasma in the center; the incoming laser pulse drives through it like a speedboat on water, picking up free electrons in its wake and hurling them forward like a surfer on a following wave. Another kind of LPA is a jet of supersonic gas a few hundred micrometers in diameter. The laser pulse drills through the gas, simultaneously ionizing it to form a plasma and leaving a wake to accelerate the free electrons. A critical challenge was how to introduce the second laser pulse, using a mirror, within the few-millimeter space between the two stages. The electron beam would have to pass through a hole in the mirror. The reflected laser pulse would come close behind. Unfortunately, to focus enough power to accelerate the electron beam, the laser focus would have to be so close to the mirror it would blow it to pieces. They first developed a prototype mirror of water film, he says, "but settled for much more robust VHS tape. The electron beam pierces the tape virtually untouched. On the opposite side, in the merest fraction of a second before the laser pulse can penetrate the tape, it ionizes the surface to form a dense, perfectly flat plasma: Steinke, whose dissertation involved plasma mirrors and who was a postdoc at the Max Born Institute in Berlin before joining the BELLA Center, characterized the mirror system for the staging experiment. Previous plasma mirrors were based on expensive solid optics made for completely different purposes. Steinke and Leemans agree: In the gas-jet LPA, the first laser pulse created an electron beam that passed through the tape, while the plasma mirror reflected the second laser pulse. Electron beam and laser pulse both entered the stage 2 capillary. No beam came out. Or, more optimistically, can shape and focus it. Van Tilborg called dibs on studying the problem and soon realized the pulsed magnetic field would make an excellent plasma lens. Such a fast-acting lens could find many uses, for example by conditioning beams of existing free-electron lasers. The final configurationâ€”gas-jet injector, plasma lens, plasma mirror, discharge capillary second stage, and diagnosticsâ€”showed energy gains, for significant portions of the electron beam , of around a hundred million electron-volts. The success of the experiment resulted from on-the-job discoveries plus continuous feedback between experimental observations and computer modeling. Among many other questions, intricacies of laser timing could be explored; focusing the energetic but ragged beam from the gas jet could be simulated even as the serendipitous discovery of how to actually do it was becoming a reality. Next comes the real thing. We will do the bunch transport with our capillary lens and play around with the timing of the second pulse. We should come out of the second stage with 10 GeV. The higher energy saves you.

Chapter 8 : Plasma Technology

Applications range from laser-plasma interactions to discharges for lighting, material modification and microelectronic fabrication, from microwave-beam interactions for microwave sources and plasma heating to plasma devices such as thrusters and ion and electron beam sources.

High-energy beam welding technology 2 2, the latest developments in electron beam welding and plasma arc welding The development of foreign electron beam welding can be summarized as: In Japan, an ultra-high pressure electron beam welder with an accelerating voltage of kV and a power of kW has been introduced. It can weld mm stainless steel at a time, with an aspect ratio of Japan, Russia and Germany have carried out research on double gun and wire-filled electron beam welding technology. On the basis of the first welding of the large-thickness plate, the top undercut or undercut defect is compensated by the second filling; the double-grab is used in Japan to realize the ultra-high-speed welding of the thin plate, and the reverse surface has no splash and is well formed. The successful development of bimetal and trimetal strip electronic beam welding machines in France has also attracted attention. Regarding non-vacuum electron beam welding, the wire joining of the rotating parts of the base material Al Mg0. The wire material was AlMg4. The study was done on a 25kW electron beam welder at the University of Stuttgart. Non-vacuum electron beam welding has been highly valued in the automotive industry. For example, in the manual transmission, the non-vacuum electron beam welding of the synchronizing ring and the gear has a productivity of more than pieces per hour. Recently, German and Polish scholars jointly developed a non-contact temperature measuring device installed in a vacuum chamber during vacuum electron beam welding. The measuring point has a minimum diameter of 1. Random heat flow interference, high measurement accuracy. In plasma arc welding, variable polarity plasma arc welding and aluminum alloy perforated plasma vertical welding are one of the concerns. Status of domestic high energy beam welding In China, high-energy beam welding has increasingly attracted the attention of more concerned people such as welding, physics, lasers, materials, machine tools, computers and so on. At the domestic level of equipment, there is a certain gap with foreign countries, but in terms of process research, the level is relatively close, and even in some aspects, it has its own characteristics. Domestic research on laser welding mainly focuses on laser welding plasma formation mechanism, characteristic analysis, detection, control, deep-fusion laser welding simulation, laser-arc composite heat source application, laser surfacing and so on. From the perspective of sound and electricity, Tsinghua University analyzed the acoustic signal of the penetration state, and proposed the mathematical model of the equivalent circuit and electrical characteristics of the laser welding plasma. In the suppression of the negative effects of the plasma, Zhang Xudong and Chen Wuzhu of Tsinghua University proposed The side suction method; Xiao Rongshi and Zuo Tiezhen of the National Center for Production, Research and Research Laser Technology proposed a double-layer internal and external circular tube blowing heterogeneous gas method; Liu Jinhe of Northwestern Polytechnical University proposed an external magnetic field method. Up to now, it has developed and produced hundreds of different types and functions of electron beam welding machines, and formed a technical team for research and production, which can provide low-power electronic products for the domestic market. In recent years, the introduction of key components electron guns, high-voltage power supplies, etc. The advantage of this method is that the equipment not only maintains a high level of technology, but also greatly reduces the cost. Provide users with better after-sales service. By connecting high-frequency IGBT contactless switches between the workpiece and the anode nozzle of the spray gun, the transfer arc and non-transfer arc were successfully realized. The high frequency alternates to achieve plasma spray welding under a single power source. The positive and negative half waves of the main arc are respectively powered by two DC power sources, and the workpiece aluminum is polarized. Welding, which not only stabilizes the arc, but also has a reliable cathode cleaning effect. Beijing Aeronautical Technology Research Institute carried out the "one pulse and one hole" process research of pulsed plasma arc welding; in the perforation plasma arc welding small hole characteristics and behavior detection, Harbin Institute of Technology, Beijing Institute of Aeronautical Technology and Tsinghua University respectively passed the spectrum Spectrum analysis of information, arc voltage and current, detecting the establishment, closure and pore size of small holes; Wang Xibao and Zhang Wenzhao of Tianjin University analyzed the transport operation of powder in transfer arc during plasma arc powder surfacing and its main influencing factors The iron-based alloy powder and boron carbide powder, the transport velocity distribution in the arc column under different parameters and the powder flux distribution along the cross section of the arc column are calculated.

Chapter 9 : Plasma Science and Technology

laser-plasma interactions, gyroton oscillators and amplifiers, high gradient electron acceleration, intense beam theory, plasma technology, environmental monitoring technologies, waste treatment, plasmas for generation of hydrogen-rich gas for pollution reduction in vehicles.