STOPPING POWER AND APPLICATIONS — 17 Apr 2017

Energy loss suffered by a charged particle passing through a medium is given by the Bethe formula (heavy ions)

$$-\frac{dE}{dx} = \frac{1}{4\pi\epsilon_0^2} \frac{z^2 e^4 n}{mc^2\beta}\left[\ln \frac{2mc^2\beta^2}{I(1-\beta)} - \beta^2\right]$$

$$\simeq \frac{5\times10^{-31}\, nz^2}{\beta^2}\left[\left\{\ln \frac{1.02\times10^6\,\beta^2}{1-\beta^2} - \beta^2\right\} - \ln I_{eV}\right]$$

For electrons/positrons there is both collisional as well as radiative loss:

$$-\frac{dE}{dx}\bigg|_{coll} \simeq \frac{5\times10^{-31}}{\beta^2}\, n\left[G^{\pm}(\beta) - \ln I_{eV}\right]$$

Radiative loss is higher than collisional loss for high incident velocities

$$\frac{|dE/dx|_{rad}}{|dE/dx|_{coll}} \simeq 10^{-3}\, Z_{Target}\, E_{proj}$$

Maximum collisional energy loss (per collision) is

$$\Delta E_{max} = \frac{4mM}{m+M} E_{proj}$$

Separation of isobars in AMS / Geology / Archaeology

Techniques : x-ray coincidence with ionisation loss

complete stripping if $Z_{radio} > Z_{stable}$

specific energy loss ($\Delta E - E$ measurement)

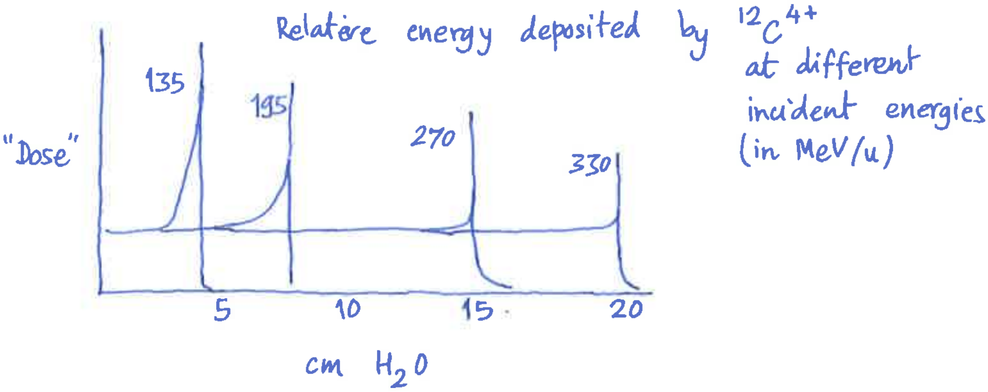
deflection in gass filled magnets

$$B\rho = \frac{M_{proj} v_{proj}}{~~qE~~ q_{proj} e} \quad \text{in vacuum}$$

$$\simeq \frac{M}{Z^{0.4}} \quad \text{in gas filled mag}$$

since $\bar{q} \simeq v^* Z^{0.4}$ (or thereabouts)

Energy loss MeV/cm vs depth cm



18 Apr 2017

Photons are a vital tool for Atomic /Molecular investigations. There is a huge variety of photon sources. Two types of sources of photons (and their derivatives) stand out because of the extraordinary properties of the emitted radiation.

1. Lasers 2. Synchrotron and a new class: free electron laser, which is a marriage of the two

Laser light is characterised by near monochromaticity, directionality and coherence

Synchrotron radiation is characterised by wide range of wavelengths with continuous variation, large divergence

Lasers are available at a number of discrete wavelengths up to the UV wavelengths. Shorter wavelengths are not available due to absence of suitable gain media.

Lasers are used for a wide range of applications. We mention here ~~few~~ two less-known but important ones from the point of view of research.

(a) Inertial Confinement Fusion

If multiple beams are incident on a sphere illuminating it strongly enough to vaporise the outer layer, in a very short time, the resulting shock wave can compress the remaining pellet. The compression can be high enough to cause nuclear reactions. If the core of the pellet has fusile material eg ^2D or ^3T, nuclear fusion can occur liberating energy.

(b) Laser-induced-breakdown spectroscopy

High power laser pulse incident on a solid can cause rapid removal of material which is a mixture of plasma and neutrals in excited state. The plume is directed away along the normal, and it can be observed without hindrance. Spectroscopy of these plumes is a powerful tool for sample testing and identification in remote conditions without the need for sample prep.

(c) Pump-probe experiments or femto chemistry

If a molecule is perturbed by a weak laser such that it is set into vibrational motion, followed by another stronger pulses that ionises or dissociates the molecule then we are able to obtain snapshots of molecular dissoc. and the transient stages in chemical reactions. These pulses of photons have to be extremely short ~ 10 fs.

(d) Higher harmonic generation

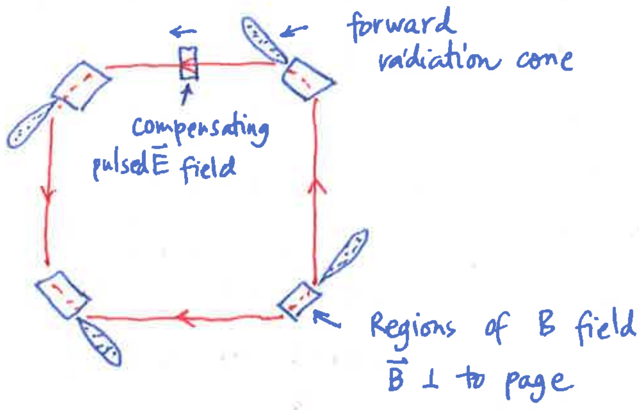
strong optical fields comparable with atomic electric fields can cause ionisation and re-collision of ejected electron following reverse acceleration, leading to the generation of high harmonics, giving coherent short wavelength radiation well into the x-ray region

Synchrotron Radiation

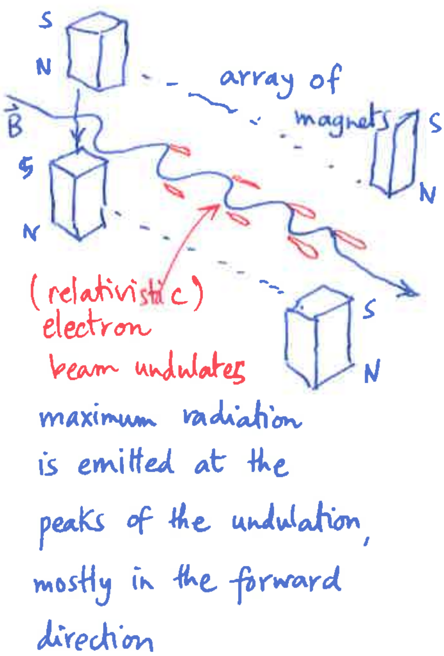
Charged particles radiate when accelerated, and high energy electrons especially so.

This fact is put to use to generate broad band intense radiation by first accelerating the electrons to GeV energies and then storing them in a closed ring. At each vertex of the polygon the electrons emit radiation. Synchrotron radiation can be monochromatised to a high degree while still retaining brightness and is used for structural and electronic properties investigations

These facilities are HUGE!



Besides radiation obtained from curved electron paths in storage rings, it is possible to obtain radiation from the electron beam subject to undulatory motion by the application of small, periodic magnetic fields transverse to the direction of propagation. this results in even brighter radiation. the radiation is plane-polarised in the plane of the undulating beam. It is incoherent and its bandwidth is inversely prop to the number of undulations, its divergence reduces as $1/N^2$ and brightness increases as N^2.



UNDULATOR ARRANGEMENT FOR OBTAINING INTENSE, DIRECTED, narrow band radiation.

Undulator radiation can be trapped in an axial cavity (two facing mirrors at the ends of the undulator) and the radiation will further influence the transverse motion of electron causing them to form microbunches moving coherently, if certain distance, energy and field criteria are satisfied. The emitted radiation then builds up coherently like in an ordinary laser, but here the relativistic electrons themselves act like the gain medium. Hence this device is called a free electron laser. (FEL)

FELs can nowadays give pulsed, coherent X-rays, although in early years only terahertz or IR radiation was possible.
For X-ray FELs the electron energies and magnetic fields of undulators are both extreme (few GeV, several Tesla)

~~You~~ Look up XFEL and PETRA facilities webpages.