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MAGNETIC RESONANCE IMAGING: A SYSTEMATIC REVIEW

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ABSTRACT

MRI (Magnetic Resonance Imaging) scanners has major role in diagnosing complex diseases. Super conducting magnet was one of the essential parts in MRI scanner, which dissipates heat while in running condition. So an external cooling system has been used to cool the superconducting magnet. In existing case liquid helium was used as the cooling agent for cooling the super conducting magnet. However the cost of liquid helium was high and it is very difficult to handle because it is effortlessly exposable. In this paper we propose a cooling system for MRI scanner based on LASER Technology. Laser Cooling System (LCS) is a resonant technology used for cooling an object to an absolutely quite low temperature by around 40kelvin. The proposed cooling system for MRI scanner using laser provide optimal cooling and reduce cost and handling complexity.

Keywords: *Magnetic Resonance Imaging (MRI), Super conducting magnet, MRI cooling system, Laser Cooling System (LCS), LASER, Doppler Effect*

1. INTRODUCTION

MRI is an influential symptomatic instrument that the medicinal group considers as an issue of decision for visualization of delicate tissue [1]. Since production of the first human self-perceptions in 1977, MRI has turned into one of the essential devices in therapeutic diagnostics. Most MRI system utilize a superconducting magnet, which comprises of numerous coils or windings of wire through which a current of electricity is passed, making an attractive field of up to 2.0 tesla [2]. The low-field whole-body MRI magnets (<0.35 tesla) are a mix of resistive magnets with iron yoke and permanent magnets. Resistive magnets have the lowest installation cost among all types of MRI systems but require a large power consumption. The permanent-magnet MRI systems are heavy. Their installation cost is rather high but maintenance cost is low. The low-field magnets typically have relatively poor uniformity and stability. Poor uniformity results in poor image quality, although it might be adequate for some applications [3]. Maintaining such a magnetic field requires a good deal of energy, which is expert by superconductivity, or reducing the resistance in the wires to almost zero [4]. To do this, the wires are persistently washed in fluid helium at 452.4 degrees underneath zero Fahrenheit (269.1 below zero degrees Celsius) [5]. This cold is protected by a vacuum. A typical MRI scanner uses 1,700 liters of liquid helium, which needs to be topped up periodically, around 30 liters of liquid helium has to be added for every two and half month. The helium fluid is highly expensive and the treatment of the helium fluid is troublesome, because it is effortlessly exposable [6]. In this sense our work is focused to create a high effective laser cooling system (LCS) for MRI scanner

Light Amplification by Stipulated Emission of Radiation (LASER) is a device that releases light by optical intensification utilizing the stipulated emission of electromagnetic radiation [7 and 8]. LASER gives incredible application in the field of scientific, military, medical and commercial [9]. In 1975 LASER radiation has been utilized with the end goal of cooling the gases [10]. The laser cooling system works on the fundamental guidelines of Doppler Effect [11]. Doppler cooling depends on the redundant energy kicks coming out because of the assimilation of red – detuned photons spreading counter to the movement of the particle [12]. In [13], it is observed that by laser cooling of semiconductor, a temperature of 40 Kelvin is achieved.

2. MRI

MRI is a diagnostic procedure that uses a combination of large magnet, radio frequencies and a computer to produce detailed image of organs and structures within the body. Although MRI does not emit the damaging ionizing radiation that is found in X-ray and CT scan, it has a strong magnetic field [14].

Most MRI systems use a superconducting magnet, which consists of many coils or windings of wire through which a current of electricity is passed, creating a magnetic field of up to 2.0 tesla. Maintaining such a large magnetic field requires a good deal of energy, which is accomplished by superconductivity, or reducing the resistance in the wires to almost zero. To do this, the wires are continually bathed in liquid helium at 452.4 degrees below zero Fahrenheit (269.1 below zero degrees Celsius). This cold is insulated by a vacuum. While superconductive magnets are expensive, the strong magnetic field allows for the highest-quality imaging, and superconductivity keeps the system economical to operate.

The biggest and most important component of an MRI system is a magnet. The magnet of an MRI scanner provides a stable, strong and spatially uniform magnetic field within a structure that allows adequate patient access.

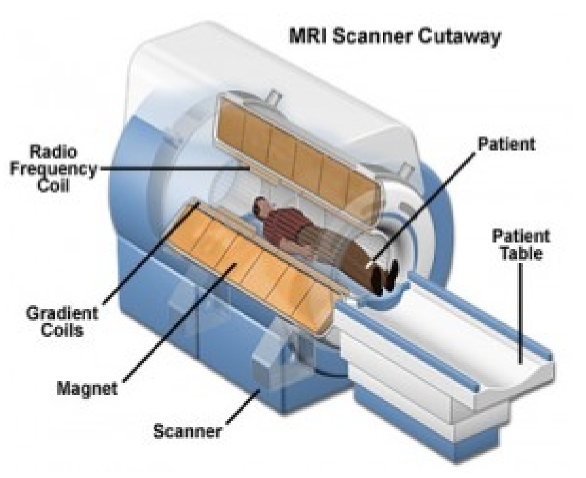

Fig1: Schematic of MRI scanner

2.1 Working of MRI

MRI scanner contains two powerful magnets which represent the most critical part of the equipment. The human body is largely made of water molecules, which consists of smaller hydrogen and oxygen atoms. Proton lies at the center of each atom, which is sensitive to any magnetic fields and hence this proton serves as a magnet. Normally the water molecules in our body are randomly arranged, but upon entering on the MRI scanner the first magnet causes the body's water molecules to align in one direction. The second magnet was then turned on and off in a series of quick pulses, causing each hydrogen atom to alter their alignment and quickly switches back to their original relaxed state, when switched off. Although the patient cannot feel these changes, the scanner can detect them and in conjunction with a computer can create a detailed cross sectional image for the radiologist [15].

Benefits of MRI

Nowadays the demand of MRI increases since it contains more remarkable advantages than other medical imaging system such as CT, x-ray. This section gives a detail list of the benefits of MRI.

a) High Spatial Resolution.

b) Exceptional description of soft tissues.

c) Functional Brain measurement.

d) No hazard for human body.

e) By changing examination parameters, the MRI system can cause tissues in the body to take on different appearances. This is very helpful to the in determining if something seen is normal or not.

f) MRI is non-invasive

g) MRI does not involve radiation

h) MRI contrasting agent is less likely to produce an allergic reaction that may occur when iodine-based substances are used for x-rays and CT scans

2.2 Cooling system in MRI scanner

The primary component of MRI is the magnet that maybe a superconductive, permanent or resistive. But superconductive magnet is the most commonly used one since it has high performance factor than others. While performing MRI generates enormous amount of heat due to the presence of superconductive magnet. Superconductive magnet has marvelous electric field due to this only the heat is generated. The heat in MRI may affect its performance. So we have to control it. For that we use cooling system.

2.2.1 Helium Cooling System

Helium Cooling System can be favorable in cases where it is very difficult to directly connect a cooler to an application due to whatever restriction there may be safety, space, noise, vibration, rotating devices etc. Advantage of gaseous Helium is its operation window. It can be used at any temperature between ambient down to approximately 10 Kelvin. Restrictions that you might have with other fluids like liquefaction and or freezing are no issue with Helium gas. If the gas is pressurized (preferably in a range of 10-20), sufficient density is available for proper heat transfer.

MRI (magnetic resonant imaging) machines work by generating a very large magnetic field using a super conducting magnet and many coils of wires through which a current is passed. Maintaining a large magnetic field needs a lot of energy, and this is accomplished using superconductivity, which involves trying to reduce the resistance in the wires to almost zero. This is done by bathing the wires in a continuous supply of liquid helium at -269.1°C. A typical MRI scanner uses 1,700 liters of liquid helium, which needs to be topped up periodically.

The problem is that helium is running out, despite being the second most abundant material in the universe, helium is scarce on Earth as its lightness means it is not gravitationally bound to the atmosphere and is therefore constantly being lost to space. The majority of the world's helium supply is created through natural radioactive decay and cannot be artificially synthesized, meaning the gas is a non-renewable resource. To overcome the difficulties of liquid Helium Laser Cooling system is employed.

During the working of MRI machine a very large magnetic field using a super conducting magnet was generated, a current was passed through many coils. A lot of energy is required for generating large magnetic field and is accomplished by super conductivity and resistance of the wire should reduce almost zero. This is done by bathing the wires in a continuous supply of liquid helium at -249 Kelvin [6].

The magnet is the most expensive part of MRI. In order to cool the system, the coil of wire is kept at a temperature 4.2 Kelvin by immersing it in liquid helium. The coil and liquid helium is kept in a large vacuum flask, this was typically surrounded by liquid helium, and this flask act as a thermal buffer between the room temperature and liquid helium [16].

As explained by Chemist Peter Wothers in the Royal Institution's 2012 Christmas Lectures, the main problem related to liquid helium is that it is running out. Despite being the second most abundant material in the universe , helium is scarce on earth as it is continuously being lost to space because of its lightness. The majority of the world's helium supply is created through natural radioactive decay and it cannot be artificially synthesized, i.e. Helium is a non-renewable resource

2.2.2. LASER COOLING SYSTEM

Since helium is of high cost it is not a preferable one. So we go for Laser Cooling system. Laser Cooling System is one of the recent technologies used to cool magnet in MRI. The temperature of a laser system can determine its lifetime, performance and safety. Many systems simply burn out if they are too hot for too long. Thermal lensing damages the beam shape of most solid-state lasers, and the output wavelength of laser diodes closely depends on their temperature.

In laser cooling, atomic and molecular samples are cooled down to nearly absolute zero through the interaction with one or more laser fields. The basic principle of laser cooling is Doppler effect. In Doppler effect the frequency of light is tuned slightly below an electronic transition in the atom. Because the light is detuned to lower frequency, the atom will absorb more photons if they move towards the light source. If light is applied from two opposite directions, the atom will scatter more photons. If this process continuous, the speed of the atom reduces and hence the kinetic energy also reduces. Which reduces the temperature of the atom, and hence cooling of the atom is achieved [17].

As per Doppler cooling, if a stationary atom sees the laser neither red-shifted nor blue shifted, it does not absorb the photon. An atom moving away from the laser sees that the laser is red shifted, then also it does not absorb photon. If an atom is moving towards the laser and sees that it is blue-shifted , the it absorbs the photon and thus the speed of the atom will get reduced. The absorbed photon excites the atom, and the electron will move to the higher energy state and the atom reemits the photon. As the direction of the emission is random , there is no net change in momentum over many absorption-emission cycles [18].

3. PROPOSED LASER COOLING SYSTEM FOR MRI SCANNER

Laser cooling system(LCS) is one of the emerging technologies used for various application to reduce the temperature of an object. The LCS operates in the principle of Doppler effects. The Doppler effect or Doppler shift is the change in frequency of a wave for an observer moving relative to its source. In recent years the laser cooling is applied for cooling the semiconductor. In the proposed system we are developing a LCS for cooling the super conducting magnet which is used in MRI scanner. The MRI scanner is a medical instrument which is more helpful for the doctors to diagnosis critical diseases. One of the most important part of MRI is super conducting magnet, which is made of copper winding. During the operation, a high voltage is passed through the super conducting magnet and thus huge heat is produced in it. Hence it must be cooled frequently, so that a cooler is adopted along with the MRI scanner. The critical temperature of super conducting magnet is 10 Kelvin (-263.15°C), hence while running the super conducting magnet , it must be maintained near to its critical temperature. In common the liquid helium is used as the cooling agent for cooling the super conducting magnet in the MRI scanner. As liquid helium has the lowest boiling point of 4 Kelvin (-269.1°C), comparatively high cost and it is complex to handle, in this proposed paper we are intend to develop a cooling system for MRI scanner which comes for long time in low cost.

In the proposed method we develop a LCS which can maintain the super conducting magnet below its critical temperature. So our aim is to model an optimal LCS which can maintain 10 Kelvin of cooling. From the previous research work related to LCS ,we have found that the temperature reduction is completely depend on the wavelength of the laser beam. In [6], Jun Zhanget al has obtained 10 Kelvin for semiconductor device cooling at the wavelength of 514 nm and at 532nm they got 15 Kelvin of cooling. So in our paper we are targeted to model the system so that the system can provide cooling up to 10 Kelvin. The block diagram of proposed system is shown below

Fig. 1.

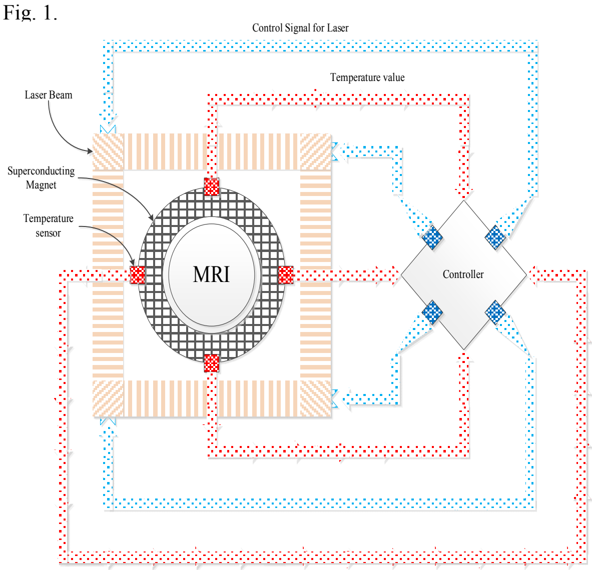

Fig. 2. Figure 2: Block diagram of LCS for MRI scanner

Here we are more concentrated on cooling system in MRI scanner. The main source of heat generation is super conducting magnet. A super conducting magnet is an electromagnet made from coils of super-conducting wire. In its super conducting state the wire can conduct much larger electric current than ordinary wires, creating intense magnetic fields. Superconducting magnets can produce greater magnetic fields than all but the strongest electromagnet can be cheaper to operate because no energy is dissipated as heat in the windings. They must be cooled to cryogenic temperature during the operation.

In this proposed system four temperature sensors are fixed on the four sides of the superconducting magnet. It can predict the temperature level at the superconducting magnet, and transmit it to the controller. So the controller has to be designed for making the cooling effective. And we have to place our model in controller so that it can provide the corresponding wavelength of laser for the predicted temperature.

4. Conclusion

Magnetic Resonance Imaging is a medical imaging technique used in radiology to investigate the anatomy and physiology of the body in both health and disease. The most important and expensive part of MRI scanner is the superconducting magnet. During the operation of MRI scanner, large amount of heat is generated because of the handling of large magnetic field. Hence an efficient cooling system is for cooling the superconducting magnet. The conventional cooling system uses around 1,700 liters of liquid helium in a typical MRI scanner. Helium is the second most abundant material in the universe. And the handling of liquid helium is also very difficult. The proposed system for MRI scanner using laser provides optimal cooling as LCS cool the system to around 10 kelvin and reduce the cost and handling complexity.

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