sotropy energy, thus requiring a large write field to reverse the media coercivity. One of the solutions to this problem is to implement HAMR where data is recorded on a high anisotropy medium by momentarily heating the medium via a laser spot to reduce its coercivity, and subsequently cooling the medium back to the storage temperature to guarantee its thermal stability, as shown in Fig. (5).

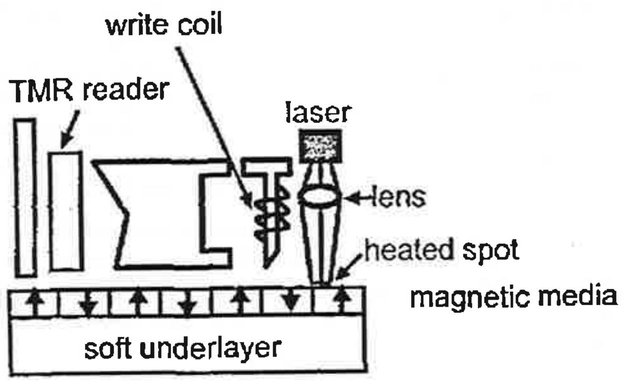

Fig. (5). HAMR system.

In order for HAMR to enhance its ability to scale conventional magnetic recording technology towards 10 Tbit/inch^2, intensive recent research has been carried out, mainly focused on the development of new recording physics, new approaches to near field optics, a recording head that integrates optics and magnetics, new coating lubricants to withstand extremely high temperature as well as new approaches to the recording channel design [11-18]. The ability to achieve 1 Tbit/inch^2 using HAMR alone in laboratory level has recently been reported [19]. Encouraged by this exciting finding, the latest results have theoretically demonstrated that it is possible to achieve the areal density of 20-100 Tbit/inch^2 on patterned FePtX media using HAMR for a reasonable range of HDD design choices [13]. However, to reproduce the theoretical estimation in practice, HAMR inevitably faces some technical challenges. First, as the areal density of HAMR media strongly depends on the laser spot, near field optical transducer has been employed in most of HAMR systems to extend the density beyond diffraction limit. In spite of the use of near field optics, the minimum laser spot size obtained experimentally is around 70 nm by means of the near field transducer, necessary for areal density of 500 Gb/inch^2 [17], and further results have revealed that it is difficult to generate a laser spot size of less than 10 nm corresponding for 10 Tbit/inch^2 [8]. Therefore, more advanced near-field optics technology needs to be developed for 10 Tbit/inch^2. Second, with the introduction of laser beam, HAMR has also caused some thermal issues that are not encountered in conventional magnetic recording. During the recording process, part of heat energy is transmitted into the spot-sized region to induce a high temperature on the coating lubricant, leading to a poor tribological performance. In addition, such high temperature is also likely to yield media thermal distortion and thermal pole tip protrusion to damage the system stability. In this case, new material such as Exchange coupled composite (ECC)-like media with high temperature stability is required. Finally, the high cost issue of HAMR cannot be avoided due to its involvement of a number of novel components such as the light delivery system, the thermomagnetic writer, a robust head disk interface and rapid cooling media.

2.2. Bit Patterned Magnetic Recording (BPMR)

Bit patterned magnetic recording (BPMR), as depicted in Fig. (6), is considered another promising technology to extend the capability of magnetic recording beyond superparamagnetism limits, in particular when combined with HAMR technology. In bit patterned media (BPM), information is stored in a uniform array of magnetic islands isolated from each other, and each island is capable of storing one individual bit, as opposed to conventional continuous media where each bit consists of a few of magnetic grains.

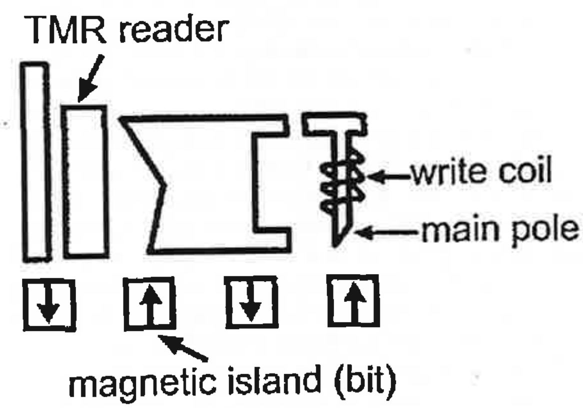

Fig. (6). BPMR system.

As BPMR has exhibited the ability to store bit in a single magnetic dot and also to reduce cross talk effect owing to the isolation between each bit, BPMR technology has been proliferating since last decade [20-27]. The areal density potential of using bit-patterned media to achieve 5 Tbit/inch^2 was been forecasted several years ago [24], and a demonstration of bit-patterned media at densities as high as 3.3 Tbit/inch^2 has recently been achieved [20]. Moreover, the feasibility of BPMR with areal density over 5 Tb/inch^2 has been verified by simulation when combined with microwave recording [23]. Nevertheless, some technical issues are currently posed along with the demand for BPMR to achieve higher areal density. First, write synchronization is needed for BPMR in which the writing field should be timely coincided with the physical magnetic island on the rotating disk, probably giving rise to the mis-recorded bit and overwriting of neighboring bit. Although some publications have proved the feasibility of writing synchronization in BPMR according to utilization of disk speed vibration, head vibration and jitter as a timing signal [19, 28, 29], more innovative synchronization methods are still anticipated for the sake of the immunity to interference when further reducing bit pitch. Second, a stringent pattern placement is required by BPMR in order to make the head follow the pattern bit tracks. It would be possible for head servo system to follow long wavelength deviations from a circular track, provided that the frequency is well within the bandwidth of the servo control system. However, it becomes difficult to follow short wavelength jogs in