The evolution of optical data storage

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The Origin of the Species. The storage capacity of 650 Mbytes on a single sided 12 cm diameter Compact Disc corresponds to a density of 1 bit per square micron, close to the fundamental limit of diffraction imposed by the use of an infrared laser with a wavelength of 780 nm. In the early 1980s, this density surpassed that of magnetic hard discs by two orders of magnitude. At the inception of the CD-ROM in 1982 it was difficult to imagine that before the end of the century this storage capacity would no longer suffice. In 1982, floppy discs, with their 1.4 Mbyte storage capacity, could still be used to distribute the operating system of a PC. Since that time, the astoundingly rapid increase of the storage capacity of hard discs and solid-state memory chips, and of the processing power of microprocessors, has triggered a software explosion. Today, the world's most popular operating system and children's computer games easily fill one or even a few CD-ROMs.

Survival of the Fittest. It is thus natural that research has been carried out world wide to find ways to store higher and higher capacities on a 12 cm disc. But the optical storage business has certain characteristics, which impose stringent boundary conditions on innovation. One must ensure that the intrinsic benefits of optical disc storage are maintained: cheap replication of pre-recorded ROM discs, robustness or "playability", removability, and a long data life exceeding 30 years. Removability also implies interchangeability of discs and players made by different manufacturers. Recordable and rewritable discs have to play back on read-only players as well. This explains why worldwide standardisation – with its associated company politics related to intellectual property rights - is important in optical disc storage, in contrast to the hard disc industry. It also explains the historical failure of many proposals for alternative optical storage technologies or systems.

Punctuated Equilibrium. As a result, the evolution of optical disc systems is one of "punctuated equilibrium", imitating the emergence of new species in natural evolution. The areal bit density of optical discs progresses step-wise rather than continuously, each step taking a considerable number of years. We will discuss the technical evolution from CD to DVD (4.7 GB, red laser based), to DVR (22.5 GB, blue laser based), and the applications of such disc systems. Options for even higher capacities include near field recording, magneto optical super resolution, or using the third dimension (multi-layered or holographic data storage). A critical review will be given.

Changing Environment. An assessment of future opportunities for optical storage requires a broader perspective. Rapid developments in data compression technology might slow down the need for more storage capacity. The emergence of wireless or wired networks, and of the internet is leading to different business models for storage and distribution of digital content. Automated personalised video recording on hard discs in the home (using adaptive user profiles) may lead to obsolescence of the traditional video recorder. Downloading MP3 files on portable appliances with solid-state storage is already becoming fashionable for portable audio. Network attached storage may replace storage in devices in the home (as it is already doing in the office). The toughest question of all: how will the end user behavior evolve? Will owning digital content in a tangible form, or "pay per usage" become the preferred model?

Biodiversity or Extinction? We will argue that hard disc storage, solid state storage, and optical storage have a good chance to coexist, whereas tape storage is likely to become extinct.