[*Continued from page 21*]

and filters can be relaxed. Laser wavelengths can be allowed to drift with changes in ambient temperature without fear that they will interfere with one another, explains Jerry Shrimpton, a consultant for Ciena Corp. (Linthicum, Md.) and what the ITU calls a rapporteur—essentially a leader—of a group studying certain issues in optical transport. Both financial and power budgets profit because thermoelectric coolers, crucial for stabilizing wavelengths in DWDM systems, are not needed.

In addition, with the wider wavelength spacing, CWDM filters are also easier and cheaper to make, because fewer manufacturing steps are needed to comply with looser tolerances.

Overall, a system based on CWDM can cost 40 percent less than if the same number of channels of a DWDM system were used, according to Paul Dickinson, technical manager of the Customer Systems Engineering Group at OFS (Norcross, Ga.), formerly the fiber-optic portion of Lucent Technologies (Murray Hill, N.J.).

Robots Stand on Own Two Feet

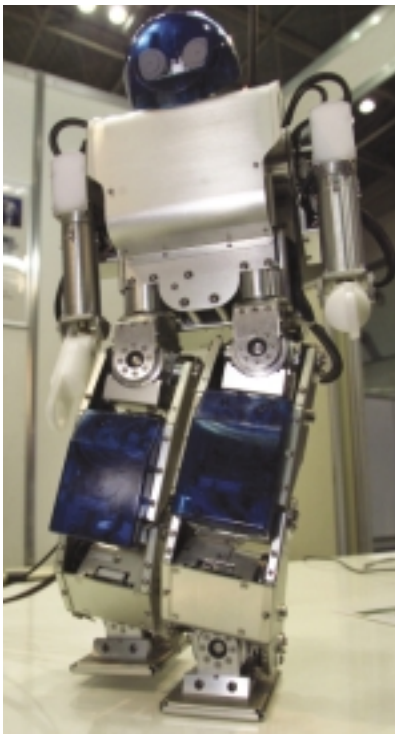
Honda, Sony, and Fujitsu selling the first strolling humanoids

ROBOTICS • The robots of our dreams walk like us, talk like us, and think like us. The robots that we've got have the agility of a golf cart and the brains of a beetle.

Though thinking remains a long-term challenge, walking and talking have made great strides lately. The latest cadre of two-legged robots walks, hops, and skips and in one instance can even dance and carry a tune at the same time. They are the fruit of several years of activity, centered, of course, in Japan, whose popular and technical cultures have long been in thrall to such machines.

For any two-legged being, the problem in walking is loss of balance. And here, height is no help. Honda's 120-cm-high Asimo is the tallest robot to amble admirably—not only on level ground, but up and down stairs and along slopes as well. To meet the challenge more easily, the latest robots scale things down: Fujitsu's new Humanoid for Open Architecture Platform (HOAP-1) is just 48 cm tall, while Sony's vaudevillian SDR-4X, the singer and dancer, is 58 cm.

Even for this diminutive duo, two-legged locomotion is no stroll in the park. In interviews at Fujitsu's sprawling research center in Kawasaki, southwest of Tokyo, senior engineers demonstrated HOAP-1 for *IEEE Spectrum* and described how it works [see photo]. Though small, the android uses a 300-MHz Intel MMX Pentium chip plus a score of 16-bit microcontrollers, each governing an individual motor that controls motion in a single degree of freedom in one of the robot's joints. There are three degrees of freedom in each shoulder and hip, two in each ankle, and one for each knee and elbow.



Fujitsu's HOAP-1 ambles along, relying on 20 motors and microcontrollers and an Intel MMX Pentium chip.

TOSHIYUKI AIZAWA/REUTERS

The key sensors are a gyroscope and accelerometers in the upper torso. These let the Intel processor keep track of the

To be sure, the coarse kind of system provides far fewer channels: the CWDM grid explicitly defines only 18 wavelengths, from 1270 nm to 1610 nm, whereas dense systems squeeze hundreds of channels into a single fiber strand. But the technology is a good match for metropolitan-area networks, which do not need the huge capacity of long-haul DWDM systems. Still, metro-area networks often cannot afford to throw away any CWDM capacity, which is what happens when CWDM is used with conventional single-mode fiber and even with advanced fibers such as OFS's TrueWave and Corning's LEAF.

Those fibers all have a water-absorption peak that pretty much incapacitates four or five wavelengths in the range of 1360–1460 nm, what is known in fiber circles as the E-band [see graph, p. 21]. Losing that 100-nm swath of spectrum would detract heavily from the value of CWDM.

Fortunately, fibers have been developed to solve the problem. First OFS, and now others, have figured out how to make optical fibers without the hydroxyl ion (OH^-) that leads to the water absorption, and full-spectrum fibers like OFS's AllWave and Corning's SMF-28e are in commercial use.

With those fibers well established and the new ITU Recommendation ensuring stable technical specifications, the stage is set for rapid growth in metro-area networking. Worldwide, according to a report from Gartner Dataquest (a subsidiary of Gartner Inc., Stamford, Conn.), the optical metro network market is expected to climb from US $1.1 billion in 2001 to $4.3 billion by 2005. This may not solve all the industry's problems, but it's a step in the right direction. **–Michael J. Riezenman**

robot's center of gravity and move the legs to keep the robot strolling smoothly. There are also sensors in the heel and toe of each foot to sense force, according to Yuichi Murase, a hardware designer on the team of eight engineers who built HOAP-1. These tell the main processor which foot is supporting the robot's weight at any instant and help it determine when to lift the other leg. In a demonstration, HOAP-1 not only walked up some stairs but also hopped nimbly from one leg to the other and swayed from side to side, like a belly dancer on a storm-tossed boat.

At maximum output, with all those motors and processors going at once, the robot consumes over 150 W. When powered only by its on-board nickel-metal hydride batteries, HOAP-1 can walk for about 20 minutes at most. Thus the preferred mode of operation is to tether it to a more robust power supply, with central processing duties handled by a more powerful, 700-MHz Pentium processor.

HOAP-1 runs a standard, real-time version of the Linux operating system, says Fumio Nagashima, who led software development. For walking, it uses a neural-network–based program. Fujitsu has sold a couple of dozen of the robots for 5 million yen or so apiece (about US $42 000), mostly to Japanese universities experimenting with robot ambulation and control. For that price, Fujitsu also throws in a simulator and other software development tools.

Beetle-brained but mellifluous

More talented than the Fujitsu's HOAP-1, Sony's SDR-4X adds sight, speech, hearing, and eight more degrees of freedom, mostly in the neck, body, and arms. The robot, controlled by two 64-bit central processors (Sony won't say who makes them), also has an array of entertaining features, mostly linked to two color video cameras and seven microphones embedded in its head. The cameras and microphones are coupled to software for obstacle avoidance and image and voice recognition—the robot recognizes the faces and voices of 10 people, Sony claims.

Among the robot's phrases, uttered in a high-pitched squeak, is "Please hold still for a minute while I memorize your face." The robots can even dance and sing in four-part harmony, says Sony, which already sells a $1500 toy robotic dog called Aibo.

While Fujitsu's Nagashima speculates about using the descendants of HOAP-1 some day for tedious farming chores, Sony is aiming SDR-4X squarely at home entertainment. But probably not in your home, unless this article finds you trying to decide whether to buy a new high-end German road machine or an unbelievably expensive toy.

Sony won't say what the robot will cost when it is released to the market at the end of this year, but promises that it will cost as much as a luxury car. So, if you are willing to forego that vacation home, for about the same pr ice you can be among the first to enjoy "Sweet Adeline" sung by your very-own quartet of beetle-brained but mellifluous mechanical marvels. **–Glenn Zorpette**

Indian Handheld Bridges Digital Divide

A handheld device born in Bangalore stirs interest in Maine

NETWORKING • A digital assistant intended to be shared and so help close the digital divide in a poor country will soon also be helping readers in the schools of a wealthy nation. An uncomplicated handheld computer [see photo, p. 27], Simputer reads Web pages aloud in Indian languages. As it happens, it has now been chosen by GraffitiWorkz Inc. (Ellsworth, Maine), a commercial library portal, to supply U.S. schools with access to a library of recently released digital titles—for a subscription, of course.

The first batch of Simputers rolled out in India in April, to be deployed in pilot projects there, and a newer version was released last month.

Developed by engineers from the Indian Institute of Science and from Encore Software Ltd., both in Bangalore, Simputer is a Palm-like device, only sturdier and with more memory and a more powerful processor on board. The initial version is based on Intel's StrongArm microprocessor and GNU/Linux software.

Its browser-like interface, which is independent of the underlying network